U.S. Army Center for Health Promotion and Preventive Medicine

19990518 125

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EPIDEMIOLOGICAL CONSULTATION REPORT NUMBER 29-HE-6781-98
OVERHYDRATION WITH SECONDARY HYPONATREMIA
FORT BENNING, GEORGIA
1997

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Readiness Thru Health

U.S. Army Center for Health Promotion and Preventive Medicine

The lineage of the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) can be traced back over 50 years. This organization began as the U.S. Army Industrial Hygiene Laboratory, established during the industrial buildup for World War II, under the direct supervision of the Army Surgeon General. Its original location was at the Johns Hopkins School of Hygiene and Public Health. Its mission was to conduct occupational health surveys and investigations within the Department of Defense's (DOD's) industrial production base. It was staffed with three personnel and had a limited annual operating budget of three thousand dollars.

Most recently, it became internationally known as the U.S. Army Environmental Hygiene Agency (AEHA). Its mission expanded to support worldwide preventive medicine programs of the Army, DOD, and other Federal agencies as directed by the Army Medical Command or the Office of The Surgeon General, through consultations, support services, investigations, on-site visits, and training.

On 1 August 1994, AEHA was redesignated the U.S. Army Center for Health Promotion and Preventive Medicine with a provisional status and a commanding general officer. On 1 October 1995, the nonprovisional status was approved with a mission of providing preventive medicine and health promotion leadership, direction, and services for America's Army.

The organization's quest has always been one of excellence and the provision of quality service. Today, its goal is to be an established world-class center of excellence for achieving and maintaining a fit, healthy, and ready force. To achieve that end, the CHPPM holds firmly to its values which are steeped in rich military heritage:

★ *Integrity is the foundation*
★ *Excellence is the standard*
★ *Customer satisfaction is the focus*
★ *Its people are the most valued resource*
★ *Continuous quality improvement is the pathway*

This organization stands on the threshold of even greater challenges and responsibilities. It has been reorganized and reengineered to support the Army of the future. The CHPPM now has three direct support activities located in Fort Meade, Maryland; Fort McPherson, Georgia; and Fitzsimons Army Medical Center, Aurora, Colorado; to provide responsive regional health promotion and preventive medicine support across the U.S. There are also two CHPPM overseas commands in Landstuhl, Germany and Camp Zama, Japan who contribute to the success of CHPPM's increasing global mission. As CHPPM moves into the 21st Century, new programs relating to fitness, health promotion, wellness, and disease surveillance are being added. As always, CHPPM stands firm in its commitment to Army readiness. It is an organization proud of its fine history, yet equally excited about its challenging future.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
August 1997

3. REPORT TYPE AND DATES COVERED
Final

4. TITLE AND SUBTITLE
Overhydration with Secondary Hyponatremia, Fort Benning, Georgia

5. FUNDING NUMBERS

6. AUTHOR(S)
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US Army Center for Health Promotion and Preventive Medicine
Directorate of Epidemiology and Disease Surveillance
Aberdeen Proving Ground, MD 21010

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
US Army Center for Health Promotion and Preventive Medicine
Directorate of Epidemiology and Disease Surveillance
Aberdeen Proving Ground, MD 21010

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
29-HE-6781-98

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for Public Release, Distribution is Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
Martin Army Community Hospital (MACH), Ft. Benning, Georgia requested an epidemiological consultation (EPICON) in July 1997 to investigate 5 cases (1 fatal) of hyponatremia in basic trainees. The EPICON team was tasked to examine the nature, magnitude, causes, and risk factors related to this problem, and to provide recommendations to prevent further cases. Ft. Benning hospital databases and medical surveillance sources were searched to define problem. Hospital databases were searched for cases of low serum sodium in association with physical activity seen in the emergency rooms and cases of hyponatremia at Ft. Benning for 1996-1997 were reviewed. Surveillance sources included Army Medical Surveillance Activity (AMSS) database and the Total Army Injury and Health Outcomes Database (TAIHOD) which were examined for heat injury and hyponatremia. Nine cases of hyponatremia and 2 cases of pneumonia with secondary hyponatremia were found in previously healthy individuals at Ft. Benning during 1996-97. All cases were associated with heat stress and many were associated with moderate to heavy physical activity. Where water consumption data were obtained, all were associated with large oral intake of water. The AMSS data revealed that between 1989-1996 there were an average of 16 cases of hyponatremia/yr. Forty percent of the hyponatremia cases were at Ft. Benning. The TAIHOD data demonstrated hyponatremia rates of 1/100,000 soldier-yrs from 1980-1988 with a gradual rise over the next four years to 12/100,000 soldier-yrs which has remained stable since 1990. Evidence gathered at Ft. Benning suggested that the hyponatremia cases may have been due to hypervolemic hyponatremia (overhydration). The team concluded that 1) overhydration with secondary hyponatremia is a problem at Ft. Benning and in the Army, 2) overhydration and hyponatremia resulted from success in enforcing fluid consumption policy to prevent heat injuries, and 3) there were 9 times more heat illnesses with hypernatremia compared to heat illnesses with hyponatremia in Marine Corps recruits. This and Army heat injury data suggest that heat injury is a larger problem than overhydration. The strong emphasis on heat injury prevention is appropriate.

14. SUBJECT TERMS

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

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1. BACKGROUND AND PURPOSE. In July 1997, the Martin Army Community Hospital (MACH), Fort Benning, Georgia, requested an epidemiological consultation (EPICON) to investigate five cases of hyponatremia in trainees. One of these cases was fatal. An EPICON team assembled to examine the nature and magnitude of the problem, the possible causes and risk factors for these cases, and to provide recommendations for the prevention of further cases.

2. METHODS.

a. The EPICON team consisted of consultants in the fields of medicine, epidemiology, thermal and exercise physiology, and nephrology. The EPICON team collaborated in working group sessions to review cases, define the problem, review current local and Army-wide water replenishment policy, establish goals and objectives for continuing action, and develop recommendations for immediate and future implementation.

b. The team searched the Fort Benning hospital databases, medical surveillance sources, and the literature to define and clarify the magnitude of the problem. The team searched hospital databases for cases of low serum sodium in association with physical activity that had reported to emergency rooms. The team reviewed cases of hyponatremia at Fort Benning for 1996–1997. Surveillance sources included Army Medical Surveillance System (AMSS) database and the Total Army Injury and Health Outcomes Database (TAIHOD). The EPICON team examined these databases for heat injury and hyponatremia. The literature review focused on causes of hyponatremia, and, as a consensus developed among team members, hypervolemic hyponatremia.

c. The team presented information and data they had gathered at a series of team meetings. Following discussions at the meetings, the team formulated probable causes and recommendations by consensus.

3. RESULTS.

a. Cases. Nine cases of hyponatremia and two cases of pneumonia with secondary hyponatremia were found in previously healthy individuals at Fort Benning during 1996–1997.

All cases were in a setting of heat stress, and many cases were associated with moderate to heavy physical activity. Where water consumption data were obtained, all were associated with large oral intake of water.

b. Surveillance.

(1) The AMSS data revealed that between 1989-1996 there were an average of 16 cases of hyponatremia per year. Forty percent of the hyponatremia cases were at Fort Benning. The TAIHOD data demonstrated hyponatremia rates of 1/100,000 soldier-years from 1980–1988 with a gradual rise over the next 4 years to a rate of 12/100,000 soldier-years which has remained stable since 1990.

(2) The AMSS data revealed an average of 117 heat injury cases per year between 1990–1996. Nineteen percent of the heat injury cases were at Fort Benning. TAIHOD data shows an increasing trend in heat injuries beginning in 1982 with peaks in 1985, 68/100,000 soldier-years, and in 1991, 85/100,000 soldier-years, before declining to 1981 levels, 28/100,000 soldier-years, at the end of 1996. (The 1991 peak is probably associated with the Persian Gulf deployment.)

(3) Serum sodium levels reported for Marine recruits with exertional heat-related injury show that hypernatremia is 9 times more prevalent than hyponatremia.

c. Literature Review. Normal serum sodium levels vary between 135–148 mEq/L (65), and hyponatremia can be defined as serum sodium below 135 mEq/L (27). Case reviews, professional experience, and an examination of Army water doctrine suggested that the hyponatremia cases reported at Fort Benning may have been due to hypervolemic hyponatremia (overhydration). The literature review focused on hypervolemic hyponatremia, although other causes of hyponatremia were not immediately ruled out. See Appendix B.

4. CONCLUSIONS.

a. Overhydration with secondary hyponatremia is a problem at Fort Benning and throughout the Army.

b. Overhydration and hyponatremia resulted from success in enforcing the fluid consumption policy designed to prevent heat injuries.

c. There were 9 times more heat illnesses with hypernatremia compared to heat illnesses with hyponatremia in Marine Corps recruits. This and Army heat injury data suggest that heat injury is a larger problem than overhydration. The strong emphasis on heat injury prevention is appropriate.

5. RECOMMENDATIONS.

a. Continue to emphasize heat injury prevention with appropriate hydration, but foster the understanding that overhydration can result in serious complications in some individuals.

b. Refer to cases as overhydration with secondary hyponatremia to emphasize that the problem results from an overconsumption of fluids.

c. To increase recognition of overhydration cases and reduce the time from onset to treatment, change Policy Memorandum No. 97–14 (Treatment and Evacuation of Heat Casualties) as follows:

(1) Add "and/or two episodes of emesis" to paragraph 3g(1).

(2) Change paragraph 3g(3) to read "after 1 hour of hydration."

d. Request that the Preventive Medicine Service, MACH, and the U. S. Army Center for Health Promotion and Preventive Medicine develop a questionnaire for use by the Emergency Medicine Department to capture demographic and risk factor data on each case.

e. The U.S. Army Research Institute of Environmental Medicine (USARIEM) and the Nephrology Department at Madigan Army Medical Center made corrections to the Army fluid replacement guidelines and submitted the corrections to the Commander, MACH in 1997 (Appendix G). Ensure corrected guidelines are validated by USARIEM. See Appendix H for the current policy guidance from the Office of The Surgeon General for fluid replacement during training.

f. Ensure continuing activities include the elucidation of environmental, demographic, and physiologic factors that bear on the development of overhydration with secondary hyponatremia in military trainees in a hot climate.

g. Conduct an in-depth epidemiological study of long-term trends of hospitalizations for heat-related injury and overhydration Army-wide.

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1. REFERENCES. Appendix A contains references used in this report.

2. INTRODUCTION. On 28 July 1997, Martin Army Community Hospital (MACH), Fort Benning, Georgia, notified the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) of one case of hyponatremia (serum Na=125mEq) associated with physical activity in the heat. At that time, the case was responding well to treatment in the Intensive Care Unit at MACH. There had also been one similar case (serum Na=119) 2 weeks earlier, which terminated fatally. Subsequently, three other cases of heat-induced hyponatremia had been identified from 25 June through 28 July 1997. The hospital commander requested an epidemiological consultation (EPICON) to assist in determining the nature and extent of the problem, the causes and risk factors for these cases, and ways to prevent further cases.

a. The term hyponatremia indicates that body fluids are diluted by an excess of water relative to solutes. Normal serum sodium levels vary between 135-148mEq/liter, and hyponatremia can be defined as serum sodium below 135mEq/liter (27). Hyponatremia can be the result of a number of sodium and water disorders, such as sodium and water depletion (volume depletion); sodium retention and edema; adrenal insufficiency; syndrome of inappropriate antidiuretic hormone; and primary dilutional, essential (sick cell syndrome), osmotic (hyperglycemia, mannitol), and artifactual (hyperlipemia, hyperproteinemia, laboratory error) hyponatremia (35).

b. The otherwise healthy condition of the cases and the hot environmental setting at Fort Benning suggested that volume depletion was the probable etiology for the hyponatremia. However, case reviews and an examination of the fluid replacement policy at Fort Benning indicated that primary dilutional hyponatremia, probably induced through overhydration, was the correct diagnosis. U.S. Army Infantry Center (USAIC) Regulation 40-14, Prevention of Heat Injury (29 May 1990), provides guidelines for the amount of water to be consumed each hour for heat categories 1-5. The training cadre also modify the amount of fluid consumed per hour based on the amount and type of trainee activity. Adherence to, and monitoring of, rest cycles is a prime concern. Trainees are observed closely during the first 14 days of training while acclimatization is occurring.

c. A review of the medical literature suggested that the combination of high ambient temperature, physical activity, and vigorous fluid replacement can produce primary dilutional hyponatremia in healthy individuals.

3. OBJECTIVES. The objectives of the EPICON were to:

a. Define the problem that resulted in symptomatic hyponatremia/overhydration among infantry trainees at Fort Benning.

b. Better understand the underlying physiologic and epidemiologic nature of the problem.

c. Determine the magnitude of hyponatremia/overhydration at Fort Benning and throughout the Army.

d. Recommend actions to understand and reduce/prevent the future occurrence of the problem.

4. EPICON TEAM. At the request of COL Newcomb, Fort Benning U.S. Army Medical Department Activity (MEDDAC) Commander, the USACHPPM formed an EPICON team consisting of a panel of experts in the areas of epidemiology, physiology, and clinical nephrology. Following is a list of team members:

a. LTC Stephen Craig, team chief, USACHPPM.

b. Dr. Joe Knapik, exercise physiologist, USACHPPM.

c. Dr. John Brundage, epidemiologist, USACHPPM.

d. COL Howard Cushner, nephrologist, Madigan Army Medical Center (MAMC).

e. Dr. Michael Sawka, thermal physiologist, U.S. Army Research Institute of Environmental Medicine (USARIEM).

f. CPT Scott Montain, thermal physiologist, USARIEM.

g. LTC Paul Amoroso, USARIEM.

h. Dr. Bruce Wenger, USARIEM.

i. MAJ William Corr, Preventive Medicine Service, Fort Benning.

j. MAJ Karen Kerle, MACH.

k. COL Bruce Jones, USACHPPM.

5. METHODS.

a. The EPICON team met twice via video teleconference to discuss the potential etiology of the hyponatremia cases as well as organizational and planning issues prior to deploying.

b. The team chief delegated specific tasks to team members from each organization. Team members prepared briefings for presentation at a group meeting.

c. The team reviewed cases of hyponatremia at Fort Benning for 1996-1997. The team defined a case as any soldier found to have a serum sodium of 130 mEq/L or less that was associated with exertion, physical training, road marches, training at the weapons range, etc., by emergency room evaluation.

d. The team searched surveillance databases to define the magnitude of the problem in the Army.

(1) We conducted a comprehensive literature review using Medline sources. See Appendix B.

(2) Dr. John Brundage searched the Inpatient Data System (IPDS) portion of Army Medical Surveillance System (AMSS) for the years 1989-1996. The International Classification of Disease (ICD)-9 code for "hyposmolality and/or hyponatremia" is 276.1. For surveillance purposes, a case was defined as:

(a) An only and/or primary diagnosis of 276.1.

(b) Any diagnosis of 276.1 plus any heat-associated diagnosis (ICD-9 code 992.x).

(c) Any diagnosis 276.1 plus any diagnosis of "fluid overload" (ICD-9 code 276.6).

All incidence of heat injuries between 1989 and 1996 were also obtained.

(3) LTC Paul Amoroso, USARIEM, searched the Total Army Injury and Health Outcomes Database (TAIHOD) for the years 1980-1996. From the IPDS portion of the TAIHOD, all diagnoses with an ICD-9 code of 276.1 (hyposmolality and/or hyponatremia) were selected by year. This included any case with this diagnosis in any of the eight discharge diagnoses fields. Also, all diagnoses with a STANAG (the North Atlantic Treaty Organization (NATO) standardization agreement system for injury classification) code of 80* (excess heat or insulation) were selected by year. Incidence rates were determined by dividing the cases by the total Army strength for that year (from the Worldwide U.S. Active Duty Military Personnel Casualty Database for Army personnel) and calculating cases/100,000 soldier-years.

(4) Dr. Bruce Wenger, USARIEM, provided data on exertional heat illness cases at the Naval Hospital, Beaufort, South Carolina (Parris Island) for 1980-1994, for which serum sodiums were obtained (Table 1). (All tables are in Appendix C.) Exertional heat illness was defined as a spectrum of disorders including exertional dehydration, heat cramps, heat exhaustion, exertional heat injury, rhabdomyolysis, and heat stroke.

e. The team met at Fort Benning 27-29 August 1997.

(1) The team presented information and data they had gathered for in-depth discussion at the meeting. Appendix E contains the briefings presented at the meeting.

(2) The team interviewed an officer from the Infantry Training Brigade to determine how Army heat injury doctrine (water replacement policy) was implemented during initial entry training (IET) at Fort Benning. Implementation of the water replacement policy was to have begun in June 1997. The policy was aggressive and thorough. Each trainee carries "Riley" cards to keep track of the amount of fluid consumed during the day (Appendix F). Each trainee has a "buddy" mark the amount consumed on his card after he drinks. There is a forced fluid intake policy to avoid heat injury.

(3) The EPICON team determined the probable cause of the hyponatremia outbreak by review of the clinical, epidemiologic, and physiologic data presented.

f. By consensus, the team arrived at recommendations for the prevention of hyponatremia at Fort Benning. The team presented the recommendations to the hospital commander, MACH, prior to departing Fort Benning.

6. RESULTS

a. Case Reviews.

(1) As shown in Table 2, 10 cases of hyponatremia at Fort Benning met the case definition criteria during 1996 and 1997. Most cases were white and male, with hyponatremia occurring early in the training cycle, following large oral water intake (usually over a few hours). Symptoms included mental status changes, nausea, and vomiting. All occurred in a setting of heat stress, and many were associated with moderate to heavy activity. The average age was 24 years (range 18-38 years).

(2) The average serum sodium was 121mEq/L (range 116-133). Serum and urine osmolality data were incomplete in 10 of the cases. Renal function, as indicated by blood urea nitrogen and creatinine levels, was within normal limits in all but one case. Only two of the cases demonstrated an elevated rectal temperature, and both of these cases had a primary diagnosis of infectious etiology (one pneumonia and one gastroenteritis). The fatal case had cerebral edema confirmed by computed tomograph scan and pulmonary edema confirmed by chest radiograph.

b. Surveillance Data.

(1) From the AMSS data, we identified 125 hospitalized cases that met one or more of the criteria in paragraphs 5d(2)(a) through (c) of this report. The average number of hyponatremia cases per year was 15.6 (range 10-26). Males accounted for 84.8 percent of cases. Figure 1 shows the cases plotted by month for 1989-1996. (All figures are in Appendix C.) The majority of hyponatremia cases (67 percent) occur in the summer months, May through September. Figure 2 shows the distribution of cases by Army medical treatment facility. About 40 percent of the cases occurred at Fort Benning. Figure 3 shows heat injuries between 1990 and 1996.

(2) Over the same period, 1990-1996, there were 1399 hospitalizations for heat injury reported Army-wide. The average number of cases per year was 116.5 (range 95-399). Males accounted for 89 percent of cases, with 66 percent of the cases occurring from June through August. Nineteen percent of hospitalized cases were at Fort Benning. Of all cases hospitalized, 18 percent were heat stroke, 62 percent were heat exhaustion, and 20 percent were other heat-related injuries. The incidence of heat injury (all categories) has been declining from a high of 55 per 100,000 soldier-years in 1991 to 30 per 100,000 soldier years in 1995.

(3) Figure 4 shows the hospitalization incidence rate of excess heat/insulation and hyposmolality/hyponatremia in Army men from 1980-1996 obtained from the TAIHOD. Hyposmolality/ hyponatremia rates were at a low level (1/100,000 soldier years) from 1980-1988. From 1988-1990, rates rose, then leveled off in 1990 at a rate of about 12/100,000 soldier years from 1990-1996. Hospitalizations for excess heat/insulation show the same pattern as the AMSS data (Figure 3) in the 1990-1996 time frame: rates showed a declining trend (with the exception of a rise in 1990 due to the Desert Shield deployment). However, rates in the 1980-1982 time frame were also low, then increase in the 1983-1985 time frame to reach a level of about 60/100,000 soldier years in the 1984-1990 period.

(4) There were a total of 1043 cases of exertional heat illness with serum sodiums obtained from the Parris Island data (Table 1). Among these cases, 2.3 percent were hyponatremic (Na<135mEq/L). while 21.0 percent were hypernatremic (Na>145mEq/L). Less than 1 percent had serum sodiums less than 130mEq/L.

c. Literature Review.

(1) Normal serum sodium levels vary between 135-148 mEq/L (65), and hyponatremia can be defined as serum sodium below 135 mEq/L (27). Hyponatremia may be caused through at least four different mechanisms.

(a) One mechanism is a loss of body solutes resulting from a loss of Na^+ or intracellular solutes. Decreases in body solutes can occur because of low Na^+ intake, gastrointestinal losses (diarrhea, vomiting), sweat fluid losses, or renal disorders.

(b) A second mechanism of hyponatremia is a decrease in the fractional water content of the plasma (pseudohyponatremia). Pseudohyponatremia is usually caused by a high concentration of lipids and proteins in the plasma. Plasma osmolality is normal, but lipids and proteins have displaced serum water, and because Na^+ is dissolved in plasma water, its total serum concentration appears low.

(c) A third mechanism of hyponatremia is the addition of solute to the plasma causing isosmotic redistribution of water (hyponatremia with hyperosmolality). This can occur when there are high serum concentrations of osmotically active low-molecular weight compounds, such as glucose, and these cause fluids to move from the intracellular space to the extracellular space. Hyperglycemia or infusion of mannitol could cause this type of hypernatremia.

(d) A fourth mechanism of hyponatremia is an increase in total body water (hypervolemic hyponatremia). This can result from increased water intake or decreased water clearance (15, 35).

(2) The literature review focused on hypervolemic hyponatremia, although the EPICON team did not immediately rule out other causes of hyponatremia. The literature review is at Appendix B.

7. DISCUSSION.

a. The Army has spent considerable time and energy to establish and implement heat injury prevention doctrine to reduce preventable injuries among soldiers. Much of this doctrine is directed at reducing physical activity and increasing fluid intake as the Wet Bulb Globe Temperature (WBGT) increases (61-63). However, our data indicate that a small subset of soldiers will become hyponatremic using the current water replacement guidelines and aggressive command emphasis. Actions, therefore, must be taken to minimize the likelihood of overdrinking during training.

b. Case reviews, professional experience, and an examination of Army water doctrine suggested that the hyponatremia cases reported at Fort Benning were probably due to hypervolemic hyponatremia. Evidence for this includes nutritional intake of soldiers, water consumption histories among hyponatremic soldiers, and Army water doctrine. During basic training, nutrient and mineral intake (especially Na^+ and K^+) are at or well above recommended levels (64, 43). Where water consumption data were obtained, histories revealed a large oral intake of water. Army water doctrine also strongly encourages fluid consumption—publications suggest more than 15 L (4 gallons) of water may be required per soldier—and encourage fluid intake rates of 1.9 L/h (2 quarts/h) when the WBGT exceeds 32°C (90°F) (61-63).

c. The prevalence of symptomatic hyponatremia in military basic training can be estimated from the population data presented in Kark et al. (26) and the data presented in Tables 1 and 3.

(1) The Marine recruit population at Parris Island between 1982 and 1991 was 216,615 (26). Assuming 44,000 recruits were at Parris Island between 1980-1981 and 45,000 between 1992-1994 (extrapolations from Kark et al., Table 1 of their articles), the total population for the 1980-1994 time frame would have been 306,000 recruits. Incidence of exertional heat illness within this time frame was 6.7 cases/1000 (assuming a constant rate across the time frame), so that about 2044 exertional heat illness cases would have been estimated to occur.

(2) Table 1 of this report indicates that serum Na^+ was collected on 1043 of these cases and 7 had serum sodium below 130 mEq/L (where most symptomatic hyponatremia appears to occur (see Appendix B)). Since only about half of the exertional heat illnesses cases were obtained (1043 of 2044), it can be assumed that about 14 cases would have occurred had complete data been obtained. Thus, the prevalence of serum Na^+ below 130 mEq/L was about 5/100,000 Marine trainees. This is considerably lower than an estimate of 30/100,000 for ultramarathoners competing in a 90-km race (41).

d. Hypernatremia (serum Na^+ >145) appears to be a much larger problem than hyponatremia in the Marine recruit population at Parris Island. Using some of the same assumptions as those in the previous paragraph, the prevalence of hypernatremia in the Marine recruit population is 142/100,000. This, combined with the fact that inadequate fluid intake in the heat can severely compromise thermoregulation and physical performance (52, 30), underscores that military emphasis on drinking water remains well justified.

e. In the setting of heat stress with soldier-regulated rehydration, hyponatremia can be caused by salt and water depletion or water intoxication (overhydration). Symptoms due to either of these etiologies are similar, and this complicates a definitive diagnosis. However, vomiting is rare with salt and water depletion. When hyponatremia is diagnosed during exertional heat illness, hypervolemia should be suspected and a history of fluid consumption obtained. This provides the rationale for the recommendation to change part of Section VII in Policy Memorandum 97-14.

f. Current fluid replacement charts provide estimates of the amount of fluid required per hour to replace the fluid lost through sweating and the work-rest cycles to be used (67). These guidelines continue to increase water intake despite a reduction in workload.

(1) For example, during heat category 4 and 5 conditions, continuous moderate to heavy work would require greater than 1.5-2.0 quarts per hour to keep up with body losses. Normal gastric emptying rates average 1.3L per hour although rates can be highly variable (14, 32, 36). Therefore, it does not make sense to drink more than this even if oral fluid intake is inadequate to maintain appropriate hydration and electrolyte balance. Additionally, high heat in combination with activity will further reduce gastric emptying (36, 44, 47).

(2) Water replacement guidelines at Appendix G are designed to be consistent with a reduction in workload as the WBGT increases, with keeping core temperatures below harmful levels, and with maximum gastric emptying rates. Remember that small males and females will require less water than their larger peers. See Appendix H for the most current water replacement guidelines.

g. Fluid replacement should match sweat losses. Sweating rates are highly variable depending on heat/humidity conditions and the intensity of activity, but maximal rates appear to be about 1 L/m^2 per hour (1, 54, 55, 9).

(1) Given this fact, women who have smaller body sizes and less surface area will sweat less, in terms of volume, than larger males, at equal activity intensities. For example, it can be estimated for the 5th percentile female, in terms of body surface area, rates will be 1.4L/hour, whereas for the 95th percentile male, rates of 2.2L/hour can be expected (12). See Appendix B.

(2) Fluid intake will thus vary depending on body size. The kidneys will increase urine volume to compensate for overhydration, but may not be able to offset high rates of intake during exercise and/or heat stress. During both conditions, urine output is decreased. Therefore, if prolonged overconsumption of fluid occurred during situations where urine formation is decreased, total body water will increase.

(3) In applying guidelines specifying fixed volumes of fluid, individuals of smaller body size will be at greater risk of drinking too much. Soldiers who feel bloated should not be forced to drink more fluids due to the dangers of overhydration.

8. CONCLUSIONS.

a. Overhydration secondary to hyponatremia is a problem at Fort Benning and throughout the Army. At Fort Benning, during 1996-97, nine cases of water intoxication and two cases of pneumonia with secondary hyponatremia occurred in a setting of heat stress and moderate to heavy activity in previously healthy individuals. All cases in paragraph 6 of this report have been associated with a large oral water intake. The real problem appears to be overconsumption of fluids, not low sodium per se; therefore, the problem should be referred to as overhydration or water intoxication with secondary hyponatremia.

b. The problem with overhydration/hyponatremia results from success in enforcing the fluid consumption policy to prevent heat injuries. While the training personnel are to be applauded for their diligent efforts to reduce heat injuries among trainees, field doctrine should be modified to avoid overhydration. Soldiers and unit leaders need to understand that too much water can be harmful.

c. There were 9 times more heat illnesses with hypernatremia compared to heat illnesses with hyponatremia in Marine Corps recruits. This suggests that dehydration is a larger problem than overhydration. Efforts should continue to focus on the prevention of heat injuries.

d. Appendix G contains recommendations to reduce the risk of heat injuries in all soldiers while minimizing the risk of water intoxication. Appendix H contains even more current guidelines.

e. Further action is required to understand the pathophysiology of water intoxication considering the combined influences of heat, activity, psychological stress, and hormonal mechanisms of salt and water balance.

9. RECOMMENDATIONS.

a. Continue to emphasize heat injury prevention with appropriate hydration, but foster the understanding that overhydration can result in serious complications in some individuals. It is not widely recognized that too much fluid can be dangerous. The Infantry Training Brigade Executive Officer commented during his interview, "We didn't know you could drink too much water." The cadre should receive education that overhydration is a possibility with serious consequences.

b. Refer to cases as overhydration with secondary hyponatremia to emphasize that the problem results from consuming too many fluids.

c. Recognize and treat overhydration cases as rapidly as possible. To assist in the recognition of cases and reduce the time from onset to treatment, change Policy Memorandum 97-14 as follows:

(1) Add "and/or two episodes of emesis" to paragraph 3g (1).

(2) Change paragraph 3g (3) to read "after 1 hour of hydration."

d. Request that the Preventive Medicine Service, MACH, and the USACHPPM develop a questionnaire for use by the Emergency Medicine Department to capture demographic and risk factor data on each case. (Case definition: a soldier with a serum sodium <130mEq/L in a setting of heat stress and/or moderate to heavy activity in a previously healthy individual.)

e. Ensure continuing evaluation and modification to Army fluid replacement guidelines to appropriately estimate the amount of fluid required per hour for varying work rates and climatic conditions. The USARIEM and the Nephrology Department, MAMC, made modifications and submitted those modifications to the commander, MACH, in 1997 (Appendix G). Ensure corrected guidelines are validated by USARIEM. See Appendix H for the current policy guidance from the Office of The Surgeon General for fluid replacement during training.

f. Ensure continuing activities include the elucidation of environmental, demographic, and physiologic factors that bear on the development of overhydration with secondary hyponatremia in military trainees in a hot climate. Specifically:

(1) Are some individuals more susceptible, or can anyone become overhydrated?

(2) What is the normal serum sodium range in military trainees who exercise in the heat and drink copious amounts of fluid?

g. Conduct an in-depth epidemiological study of long-term trends of hospitalizations for heat-related injury (e.g., heat stroke, heat exhaustion, dehydration, rhabdomyolosis, etc.) and overhydration (e.g., hyponatremia, hyposmolality, volume overload, etc.) Army-wide. While the incidence of heat injuries in Marine recruits has been well documented (19, 26), there is little data on Army recruits.

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APPENDIX A

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APPENDIX B

LITERATURE REVIEW

1. Initial Recognition of Water Intoxication. Rowntree (51) first fully described the effects of acute, excessive intake of water. He called this "water intoxication" to designate the potential poisoning influence of water consumed in large quantities. Symptoms included "restlessness, asthenia, polyuria, frequency of urination, diarrhea, salivation, nausea, retching, vomiting, muscle tremor and twitching, ataxia, tonic and clonic convulsions, frothing at the mouth, helplessness, stupor and coma." He noted that the condition was accompanied by increased intercerebral pressure and by an imbalance of "body salt" that may cause some of the symptoms.

2. Case Studies of Hyponatremia in Non-Exercising Conditions.

a. Overhydration resulting in water intoxication has been reported in overfeeding of infants (56, 38, 5), as a manifestation of child abuse (34) and in psychiatric patients with psychogenic polydipsia (48,49, 11). Table 4 shows case studies of otherwise normal individuals seen in hospital settings who voluntarily consumed large quantities of water and exhibited symptoms of water intoxication. In cases where the rate of consumption was reported, it was generally very fast (7, 21, 60, 2, 29). Although, consumption periods up to 5 hours have been reported (17, 28), and, in one case, water was apparently consumed over 48 h (45). Initial serum sodiums have ranged from 101-127 mEq/L. In all but one case (2), patients recovered over time with apparently normal renal function.

b. Cerebral edema was evaluated by computed tomography (CT) in four cases (2, 29, 28, 53) and confirmed in three (2, 29,28). Pulmonary edema was evaluated in one case by chest radiograph and confirmed (2). The case with both cerebral and pulmonary edema was fatal (2). Several other fatal cases have been reported in patients (48, 49, 22). .

3. Case Studies on Hyponatremia During Exercise.

a. Table 5 shows eight cases in which individuals performing endurance exercise were admitted to hospital rooms with hyponatremia and associated overdrinking of fluids. Nelson et al. (39) and Young et al. (66) appear to have reported on the same case. Estimated fluid consumption ranged from 6 to 24 L. All cases but one (40) had symptoms consistent with water intoxication. Serum $Na+$ ranged from 115 to 125 mEq/L.

b. The studies in Table 5 also found that in two cases (39, 66, 59), cerebral CT scans were performed, and, in one case, cerebral edema was confirmed (39, 66). The cerebral edema was considered resolved on a second CT scan. In three cases (39, 66, 40), a chest radiograph was obtained and pulmonary edema confirmed. Of the eight cases, only two (40, 59) had symptoms during the race; the remainder had symptoms 5 minutes to several hours post-race.

4. Descriptive Studies on Activity-Associated Hyponatremia. Table 6 presents a summary of studies that have systematically examined various aspects of hyponatremia during physical activity.

a. Hiller et al. (23, 24) looked at plasma electrolytes in several triathlons and a single biathlon (run and cycle). Ambient temperatures in one Hawaiian Ironman triathlon "at times exceeded 100°F" (32°C). In this event, pre-race Na^+ levels were in the normal range (138-145 mEq/L), but post-exercise plasma Na^+ ranged from 114-145 mEq/L. The authors noted that 29 percent of those surveyed were "hyponatremic," but the definition of hyponatremia was not provided. In (apparently) pooling the results from two Ironman triathlons, they found 20 percent of triathletes were "hyponatremic" (27 of 136 subjects). There was no incidence of "hyponatremia" in subjects competing in the U.S. Triathlon National Championships or in the biathlon.

b. Noakes et al. (41) reported the results of two investigations on activity-associated hyponatremia. Blood samples were withdrawn from 50 percent of all collapsed finishers in two 90-km ultramarathons and from 69 percent of all finishers in a 185-km ultramarathon. In the study of collapsed finishers, 9 percent had serum Na^+ below 130 mEq/L. However, none of the finishers in the longer ultramarathon had values this low. Noakes et al. estimated the prevalence of symptomatic hyponatremia during the 90-km ultramarathon at 0.3 percent of the ultramarathoning population.

c. Irving et al. (25) examined eight hyponatremic runners who collapsed during an ultramarathon.

(1) The authors compared these subjects to 18 experienced runners, but did not state the selection criteria for these controls. Irving determined from detailed patient histories that hyponatremics had a fluid balance of +1.2 to +5.9 L; however, it appears that Irving et al. based this balance estimate mainly on fluid intake and urine output, and it is not clear if Irving et al. considered sweat or respiratory fluid loss during exercise.

(2) Plasma volume was reduced by 24 percent in the hyponatremics compared to the controls. Serum total protein and serum albumin were lower in the hyponatremics than in the controls, suggesting that hyponatremics failed to draw interstitial proteins into the plasma, and this influenced the reduced plasma volume.

(3) Irving et al. hypothesized that the reduced plasma volume would serve as a nonosmotic stimulus for both fluid intake and vasopressin release.

d. One of the most informative studies on the possible etiology of activity-associated hyponatremia is that of Armstrong et al. (4).

(1) The authors reported the case of a single subject (K.G.) who experienced hypervolemic hyponatremia during exercise in the heat; they compared this subject to nine others who did not experience hyponatremia.

(a) Blood chemistry, fluid balance, and fluid-regulating hormones were measured; dietary intake of NaCl was controlled at 137 mEq/L per day for 7 days prior to the exercise bout (within normal American adult intake). After dietary equilibration, subjects exercised at 40-45 percent VO_2max on a treadmill, alternating 30 minutes of exercise and 30 minutes of rest during an 8-hour period. Ambient environmental conditions were 41°C, 21 percent relative humidity. Subjects were encouraged to drink pure and flavored water (<1mEq Na/L) *ad libitum.*

(b) During the first 5 hours of exercise, K.G.'s body mass increased 5.3 kg, and he voluntarily consumed 10.2 L of fluid; at this point, he was instructed to curtail his fluid consumption. He was removed from the test after 7 hours because of a rash, and 3 hours later he complained of nausea and malaise. Hyponatremia was diagnosed (serum Na^+=122 mEq/L on hospital admission), 5 percent saline administered, and the subject was hospitalized. He was released from the hospital the following day.

(2) K.G. voluntarily consumed such a large volume of fluids because he believed he would reduce his heat injury risk.

(a) At 5 hours of exercise, K.G.'s fluid balance (intake minus urine and sweat output) was +4.5 l. Armstrong et al. noted that K.G. may have been moderately hyponatremic at the start of the exercise bout because plasma Na^+, osmolality, and hemoglobin were 2 standard deviations from the mean of the control subjects (134 mEq/L, 282 mOsm/kg, and 45 percent, respectively); and vasopressin, aldosterone, and plasma renin were in the "low normal" range (0.9 pg/ml, 23.7 pg/ml, and 0.9 ng/ml, respectively).

(b) K.G. appears to have experienced abnormal hormonal regulation. Blood chemistry was obtained at the end of 4 hours of exercise (when fluid balance was +3.3 L for KG and -0.3 L for the controls) and final exercise bout (fluid balance +2.5 L for K.G. and -1.2 L for the controls). At hour 4, K.G. had low aldosterone and plasma renin activity relative to the controls

despite low plasma Na^+ (126 mEq/L). Plasma arginine vasopressin was unchanged from the resting value at hour 4, but was to 4.2 pg/ml at the final period despite low plasma osmolality (253 mOsm/kg), and a plasma volume was not reduced but rather slightly expanded (+7 percent).

(3) Armstrong et al. (4) also hypothesized that the excess water intake may have been stored in the gastrointestinal tract. He noted that during exercise in the heat, the gastrointestinal area may serve as a temporary storage site resulting in a movement of Na^+ into the intestines. At hour 4, K.G. had a weight gain of 4.0 kg, only a mild diuresis (1.3 L compared to 0.2 L in the controls) and little change in hormonal levels, suggesting fluids had not been absorbed from the gastrointestinal tract at this point.

5. Body Water Balance During Exercise in the Heat.

a. Total body water balance during exercise is a function of ingested fluid input and losses due to urinary output, sweat, and respiration.

(1) The maximal fluid absorbing capacity of the small intestines is not known, but estimates in the duodenojejunum area indicate that rates in this area are at least equal to, if they do not exceed, gastric emptying rates (14). During both exercise and rest, repeated ingestion of small amounts of fluid will result in gastric emptying rates that increase as the volume of ingested fluid increases (32, 42). Maximum rates appear to be about 1.3 l/min. (14, 32, 36). However, if a very high volume of fluid is consumed, gastric emptying may be reduced and gastrointestinal distress increased (32, 10).

(2) Further, the rate of gastric emptying is reduced during exercise in the heat, and heat acclimation does not appear to improve emptying rates (36, 44, 47). Exercise in a cooler environment may actually increase the rate of gastric emptying, at least until the exercise intensity becomes very high ($\geq$75 percent VO_2max), when gastric emptying rates are again similar to resting rates (37, 20).

b. Sweating rates are highly variable, but the body can lose over 1 liter per square meter of body surface area (BSA) per hour (1, 54, 55, 9). Table 7 shows the average body surfaces for men and women and suggests that sweating rates may exceed 2.24 L/h assuming a male soldier in the 95th percentile of body mass and stature. Strydom et al. (58) reported on total sweat produced by soldiers during a 29 km military march. Soldiers carried 24 kg, drank water *ad libitum*, and marched at an average speed of 6.6 km/h. The dry bulb temperature averaged 27°C, and relative humidity was about 13 percent. The soldiers' BSA was 1.83 and they marched 4.4 hours (50 minutes each hour), so the estimated average sweating rate was 0.56 L/m^2h on the march.

c. Urine production during rest may range from 0.5-0.9 L/h. With light exercise, urine production may be unchanged or slightly increased; however, during moderate to heavy exercise, urine production decreases from 20-60 percent (67, 6). This suggests that urine production is graded to exercise intensity, but this hypothesis has not been specifically tested, and the effects of heat superimposed on the exercise bout is not known.

d. Respiratory water losses increase with exercise intensity and are not dependent on dry bulb temperature in a range of 20 to 37°C. In general, evaporative water loss from the respiratory tract is small, amounting to 0.1-0.3 L/h across a wide range of exercise intensities (33).

6. Potential Etiology of Physical Activity-Associated Hyponatremia.

a. The etiology of activity-associated hypervolemic hyponatremia is difficult to determine based on our current data. Obviously, consumption of a large volume of water is required, and the condition appears to be exacerbated by physical activity in hot-humid conditions. Reduced gastric emptying rates have been found with ingestion of large amounts of fluids during exercise in the heat (36, 44, 47). Exercise and heat stress will reduce kidney blood flow and glomerular filtration (6, 50, 67), thus reducing diuresis.

b. Some authors have argued that abnormal hormonal regulation may play a role (39, 25), but the data on this is limited to one study (4). In this study, a single subject consumed a large volume of water (10.2 L) and became hyponatremic. This individual displayed low aldosterone levels and plasma renin activity in the face of low plasma Na^+ (normally associated with higher levels of these hormones). Arginine vasopressin (ADH) levels were initially low, then became very high despite low plasma osmolality, a slightly expanded plasma volume and a fluid balance of +2.8 L (normally, stimuli for reduced vasopressin).

c. In our case series (EPICON at Fort Benning), there was one documented incidence of cerebral and pulmonary edema (Table 2), although many cases have been reported in the literature in association with hypervolemic hyponatremia (2, 29, 28, 39, 66, 40).

(1) Cerebral edema during hypervolemic hyponatremia may have been caused by an influx of fluids into the brain due to the osmotic gradient (46, 3). Pulmonary edema, where it is seen (2, 39, 66, 40), may be a direct result of the cerebral edema. Intracranial hypertension activates the sympathetic vasomotor mechanism at the medulla or cervical spinal cord resulting in an increase in left arterial pressure and bradycardia (the Cushing response). This increases the intravascular pressure resulting in elevated pulmonary capillaries pressures and the leakage of fluids into the alveoli. This is termed "cardiogenic" pulmonary edema.

(2) Sympathetic activation may also directly alter pulmonary capillary permeability either by increasing the pulmonary capillary hydrostatic pressure or a direct nervous system effect increasing pulmonary capillary permeability. This is called "neurogenic" pulmonary edema (57, 31). In one case where both cerebral and pulmonary edema occurred in a hyponatremic runner (39), the pulmonary wedge pressure was normal (7mm Hg), suggesting a neurologic mechanism.

d. While case studies and experimental investigation point to useful clues to the etiology of symptomatic hypervolemic hyponatremia during physical activity, there are still contradictory findings and unexplained phenomena that can only be resolved with further investigation.

7. Other Factors to Consider in Activity-Associated Hyponatremia.

a. Other factors that should be considered include the use of nonsteroidal anti-inflammatory drugs and the influence of physical training on vasopressin and urinary output levels. Anecdotal information suggests soldiers and athletes commonly use nonsteroidal anti-inflammatory drugs to reduce the discomfort associated with exercise-induced inflammation. Nonsteroidal anti-inflammatory drugs inhibit the production of prostaglandins, and suppression of renal prostaglandins may result in water retention (8).

b. One study (16) demonstrated a difference between endurance trained and untrained subjects in vasopressin response and urinary output to a water challenge. Vasopressin response to the ingestion of about 0.6 L of water was blunted in the endurance trained subjects, relative to untrained subjects. Urine output was also less in the trained subject due to a reduction in free water clearance, suggesting the higher vasopressin levels were involved in the reduced urine output. This suggests that endurance training alters the vasopressin response to consumption of a large volume of water and reduces urine output.

APPENDIX C

TABLES AND FIGURES

Table 1. Exertional Heat Illness Cases with Serum Sodium at Naval Hospital, Beaufort, SC, 1980–1994 (Sample n = 1043) (From Dr. Bruce Wenger)

Serum Na	Cases	Incidence (Cases/100)
<130	7	0.7
<135	24	2.3
>145	218	20.9

Table 2. Overhydration/Hyponatremia Cases, Fort Benning, 1996-1997

Age Race/ Sex Unit	DOA	Symptoms Activity	H2O qts/h	T	Na	Cl	K	Mg	S Osm	U Osm	CPK	CKMB	BUN	Cr
19 W/M A1/38	6/22/96	Lightheaded N/V, Weak, Loose stools/ Road March with MOPP		96.1	122	94	2.8				444		14	1.0
22 W/M C4RT B	7/10/96	Disoriented Seizures Diarrhea		97.0	117	90	4.0	2.1	255	239	2700		15	1.2
35 W/M C2/11	8/1/96	N/ V, Dizzy Headache	2-3	95.8	131	99	3.7						13	0.9
38 W/M A 1/507	8/20/96	Malaise,N/V Disoriented, Weak ABN TNG		98.8	116	81	3.6	1.3			2472	19	11	1.0
18 W/M B 1/507	5/12/97	Prod Cough, chills, vomiting ABN TNG		102. 2	130	99	3.4						16	1.1
18 W/M A2/54	6/25/97	Weak,Dizzy Disoriented, N/V/D x 2d Maneuvers	>2	95.1	120	86	3.3	1.2	251		457	4.9	12	0.8
21 W/M A1/19	6/25/97	Dioriented Nausea, Cramps	1	96.8	116	88	3.0	1.4	245				9	0.9
18 W/M A1/19	6/25/97	N/V,Fatigue Disoriented Wpns Range	>2	97.0	119	90	3.2	1.6	254	203	1999	8.4	9	0.8
18 Esk/ M D1/38	7/2/97	Lightheaded N/V, Sz, Coma Wpns Range	>2	98.8	121	89	3.0	1.4	253			4.0	16	0.9
18 W/M B2/58	7/26/97	Dizzy, Disoriented, Seizures Wpns Range		98.8	115	85	3.2		253		595	7.3	12	0.9

Table 3. Summary of Two Studies Examining Exertional Heat Illness During 12 Weeks of Marine Recruit Training at Parris Island, NC

Study	Years	Sample Size	EHI Cases	EHI Incidence (Cases/1000)	EHI Hospitalization Incidence (Cases/1000)	Summer EHI Incidence (May-Sept) (Cases/1000)
Gardner et al., 1996 (19)	1988-1992 (5 years)	88,000	528	6.0	0.66	ND[a]
Kark et al., 1996 (26)	1982-1991 (10 years)	216,615	1454	6.7	0.74	~20

[a]ND=No data

Table 4. Case Studies of Voluntary Overhydration and Hyponatremia in Otherwise Normal Individuals

Study	Patient	Patient Situation	Initial Serum Na mEq/l	Estimated Water Consumed	Symptoms	Treatment and Resolution
Swanson & Iseri, 1958 (60)	44-yr-old man	Vomiting for 6 days, drinking beer, whiskey and water	101	4 L plus quantity of beer and whiskey	Combative, incoherent, confused, convulsions	5% saline i.v.; discharged as clinically well after 6 days
	52-yr-old man	Drank water and rendered enema in attempt to defecate	101	24 glasses in 2 h plus 2 enemas <1 pint each	Vomiting, incoherent, agitated	Alert 14 h post episode; discharged 2 days after admission
Pickering & Hogan, 1971 (45)	9-yr-old boy	Drinking ice water to relieve tooth pain	123	9.5-14 L over 48 hrs	Vomiting, confused, convulsions	3% saline i.v. over 8 h; at 8 hrs alert & responding to mother; at 18 hrs could recall events
Goldberg et al., 1982 (21)	10-mo-old boy	Swimming lesions	123	0.8 L pool water	Tonic-clonic convulsions, apnea	Saline (230 ml), mannitol & furosemide; Discharged on 3d day
Friedman et al., 1983 (17)	28-yr-old man	Lower urinary tract obstruction	117	30-40 glasses in 5 hrs	Vomiting, nausea, restlessness, confusion, agitated, convulsions	3% saline i.v.; alert and coherent after 19 hrs
Anastassiades et al., 1983 (2)	40-yr-old woman	Ingested bleach; drinking water on advice of poison center	111	15 L	Vomiting, confused, incoherent speech, convulsions	Hypertonic mannitol; Fatal
Christenson & Scott, 1985 (7)	79-yr-old woman	Ultrasound exam	122	1.5-2.0 L quickly	Dizzy, decreased consciousness, disorientated, unable to communicate	3% saline (300ml) and 5% glucose in normal saline i.v.; next day mental status normal
Knott & Marcus, 1985 (29)	21-yr-old woman	Ultrasound exam	127	30 glasses of water, one after another	Nausea, vomiting, restless, confused, non-responsive,	5% NaCl (300 ml) and 10% mannitol (100ml) i.v.; second day normal mentation
Shapira et al., 1988 (53)	80-yr-old woman	Ultrasound exam	119	4 L	Confused, restless, uncooperative	Hypertonic saline i.v.; clinically improved in 24 hrs
Klonoff & Jurow, 1991 (28)	40-yr-old woman	Drinking water to urinate for drug test	121	3 L over 3h	Vomiting, confused, slurred speech, unsteady gait	1400 ml saline i.v. and oral K; 24 h later normal mentation

Table 5. Case Studies of Hyponatremia Associated with "Overhydration" in Exercising Subjects Admitted to Emergency Rooms

Study	Patient	Patient Situation	Initial Serum Na[a]	Estimated Fluid Intake	Symptoms	Treatment and Resolution
Surgenor and Uphold, 1991 (59)	57-yr-old male triathlete	Completed 30 miles of 100-mile race	119 mEq/l	8.5-9 l Kool-Aid	Dizzy; slurred, unintelligible speech, collapsed	Saline, Ringer's lactate, mannitol, i.v.; discharged after 3 days
Noakes et al., 1985 (40)	46-yr-old female, running 3.5 yrs	Completed 70 km of 88-km race	est 115 mEq/l on stopping running	6 l	Grand mal, comatose, random twitching	0.9% saline; 48 h mental state normal; good health after 6 days
	37-yr-old physician	Running race (not specified)	est 118 mEq/l at end of race	12 l	Muscle twitching, lapse of consciousness	0.9% saline, 5% dextrose; discharged next day
	20-yr-old student,	Running 88 km race; completed race	115 mEq/l; est 124 mEq/l at end of race	10 l	Grand mal, semi-conscious, restless	0.9% saline (4 l over 12 h); lost to follow-up after 4 days
	29-yr-old female	Competing in triathlon; finished race	est 125 mEq/l at end of race	8 l	Short of breath	diuretic, 0.9% saline; discharged after 4 days
Frizzel et al., 1986 (18)	24-yr-old male medical student	Running AMJA ultramarathon; finished second in race	123 mEq/l	20 l	Semi-awake, disoriented, inappropriate responses to verbal commands, grand mal	Normal saline i.v.; discharged 5 days after admission
	45-yr-old male physician	Running AMJA ultramarathon; completed race	118 mEq/l	24 l	Disoriented, confused, slurred speech, unpurposeful movements	Diazepam (5mg), Ringer's lactate, 3% hypotonic saline; discharged 8 h after admission
Nelson et al., 1988 (39)	21-yr-old male	Running first marathon (32°C, 85% humidity); completed race	123 mEq/l	Water at each of 16 stops and 1½ -2 l after race	Confused, agitated, disoriented, comatose, frothy sputum	Intubated, ventilated normal saline; extubated and discharged day 7
Young et al., 1987 (66)	21-yr-old male	Running first marathon; completed race	123 mEq/l	Water every 16 water stops; 2 liters post-race	Incoherent, agitated, delirium; pulmonary edema	Ringer's lactate (350 ml), dextrose (5%, 1500l); discharged after 7 days

[a] Est=Estimated

Table 6. Studies of Hyponatremia During Physical Activity

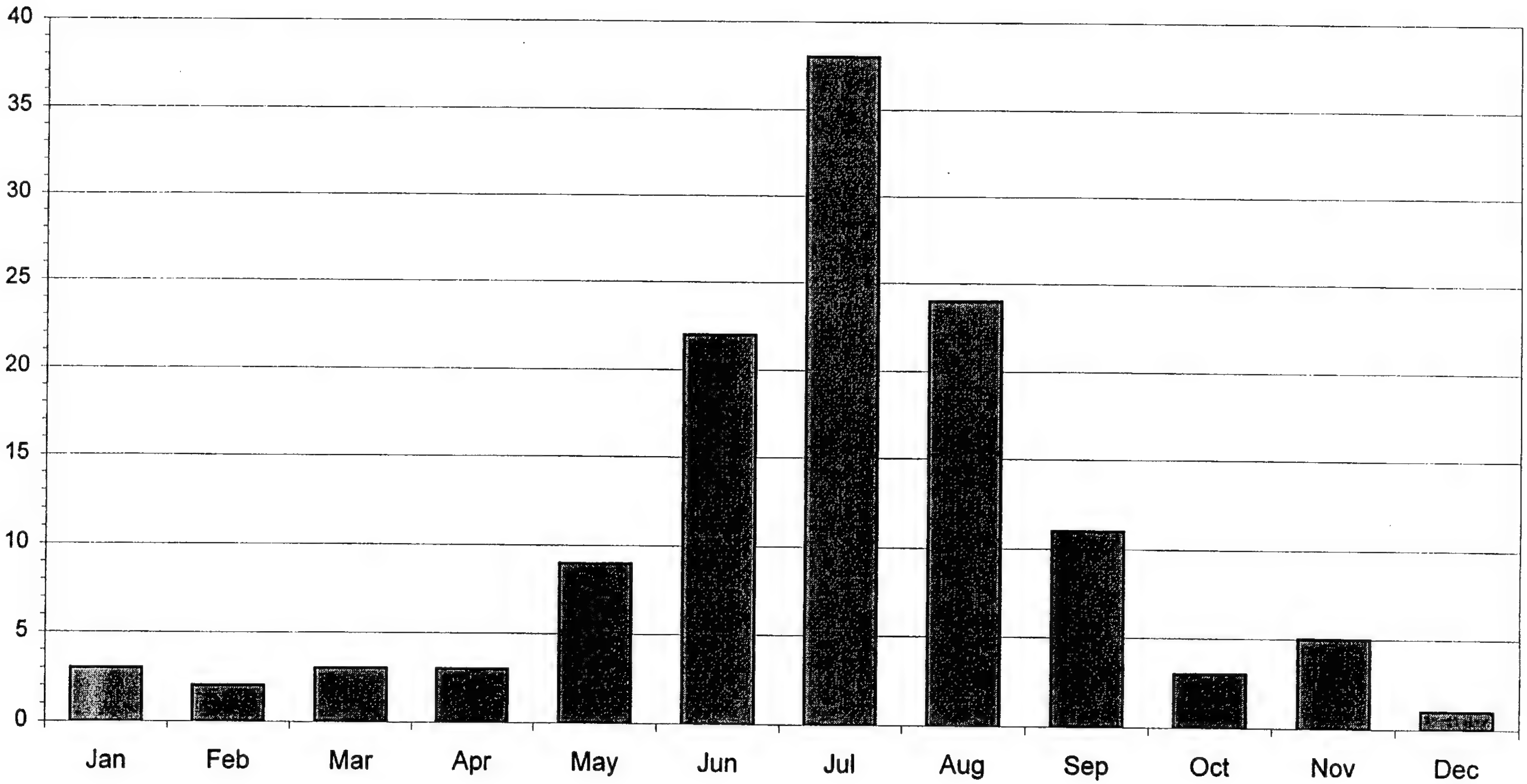
Study	Population	Sample Size	Environmental Conditions	"Hyponatremia" Definition	Incidence of Hyponatremia (cases/100)	Fluid Intake or Fluid Balance
Hiller et al., 1985 (23)	Triathletes in Ironman with blood withdrawn	64	At times exceeded 38^{o}C	"Abnormally low post-race Na"	29 (19 of 64)	Not reported
Hiller et al., 1986 (24)	Triathletes with blood withdrawn in 3 triathlons and a biathlon	190	Not reported	"Hyponatremia"	14 (27 of 190) but all cases in 2 of 4 triathlons	Not reported
Noakes et al., 1990 (41)	Collapsed finishers in 90-km Comrades Ultramarathon (1986 & 1987) who had blood drawn	315 of 626 collapsed finishers (50% of population)	30^{o}C at midday in 1987; not reported for 1986	Serum Na <130 mmoles/l	9 (27 of 315)	Not reported
	Finishers in 185- km Carling Ultratriathlon who had blood drawn	101 of 147 finishers (69% of population)	30 ^{o}C for greater part of race	Serum Na <130 mmoles/l	0 (0 of 101)	Not reported
Irving et al., 1991 (25)	Collapsed runners in 88-km Comrades Ultramarathon (1988)	~300	Not reported	Serum Na <130 mmoles/l	~3 (8 of ~300)	12.5$\pm$1.6 l (estimated in 10 h period)
Armstrong et al., 1993 (4)	Subjects in research study (8 h of 30 min exercise/30 min rest at 40-45% VO_2max)	10	41^{o}C, 21% relative humidity	Serum Na <130 mEq/l	10 (1 of 10)	10 l (N=1) 5$\pm$2 l (N=9) (fluid balance: N=1:+2.8l N=9:-1.2l)

Table 7. Body Mass, Stature and Body Surface Area of Military Personnel

		Body Mass (kg) [a]	Stature (m) [a]	Body Surface Area(m^2) [b]
5th Percentile	Men	61.6	1.65	1.68
	Women	49.6	1.53	1.44
Mean	Men	78.5	1.76	1.95
	Women	62.0	1.62	1.66
95th Percentile	Men	98.1	1.87	2.24
	Women	77.0	1.74	1.92

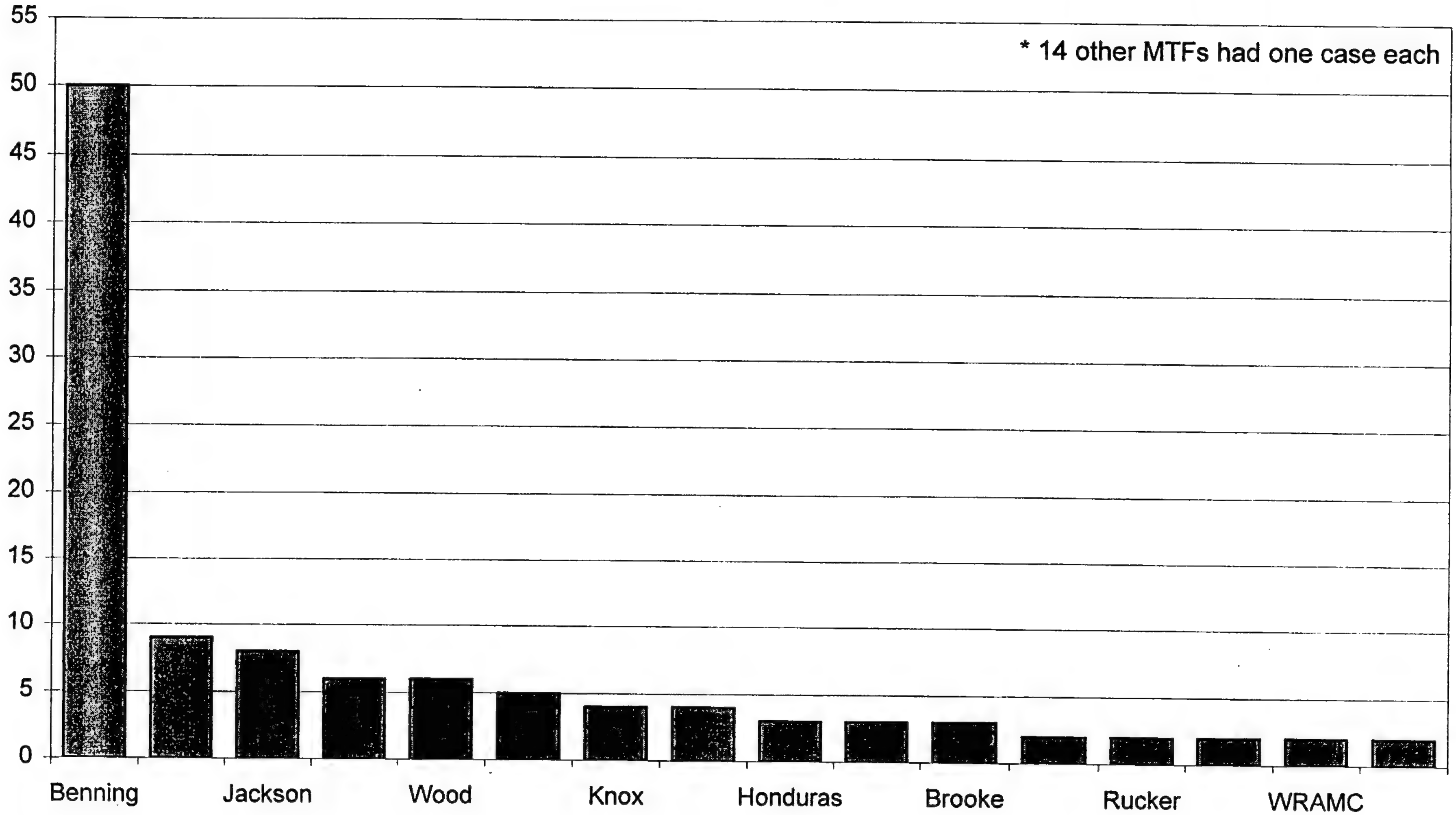
[a] From Donelson et al. (12)
[b] Based on the DuBois equation (13)

Figure 1. Monthly "Hyponatremia" Hospitalizations, US Army, 1989 - 1996



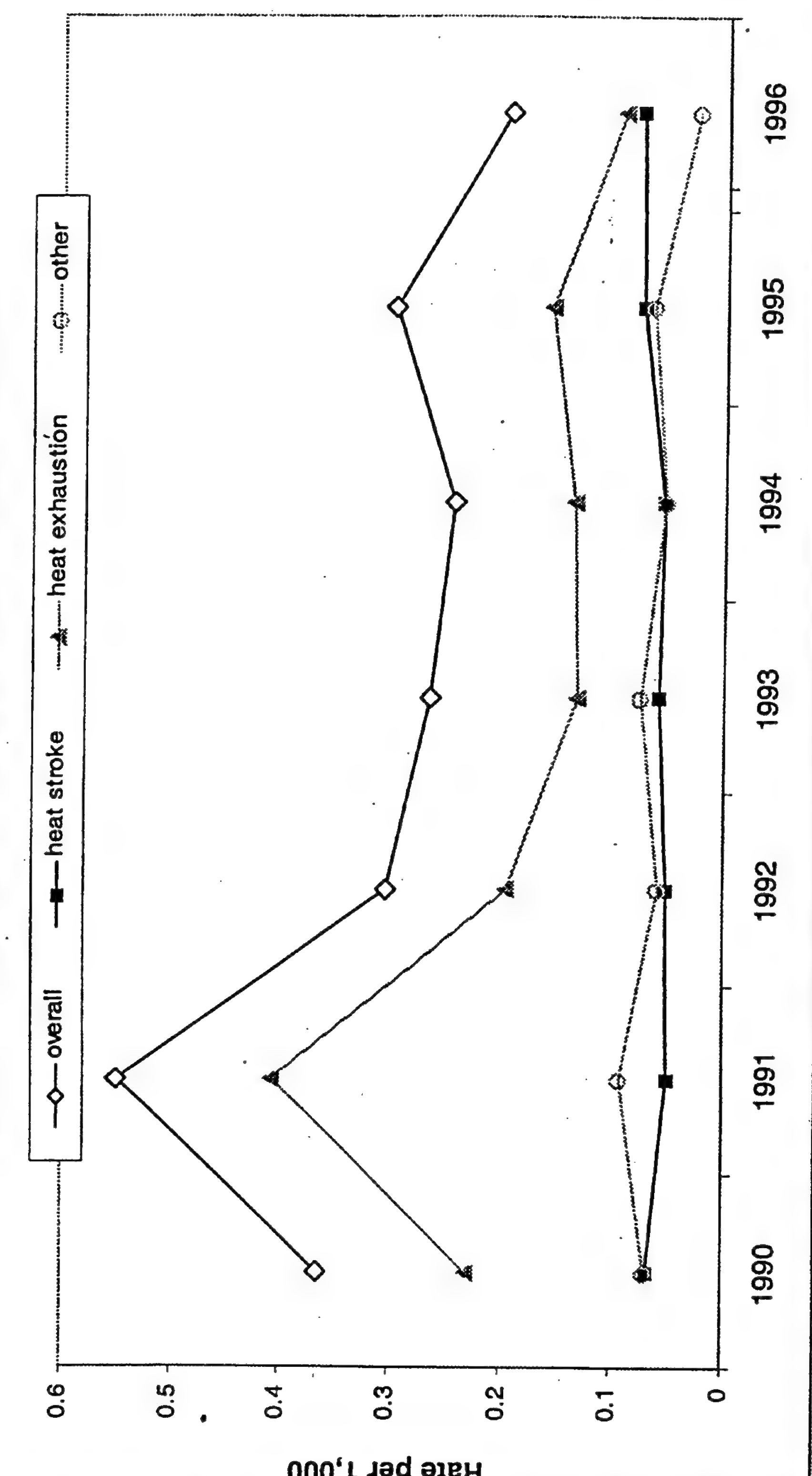
Source: IPDS, PASBA

Figure 2. Medical Treatment Facility "Hyponatremia" Hospitalizations, US Army, 1989-1996



Source: IPDS, PASBA

Figure 3. Hospitalization rates for heat injuries, 1990-1996



Hospitalizations due to Excess Heat/ Insulation and Hyposmolality/ Hyponatremia in Men in the Army 1980-1996

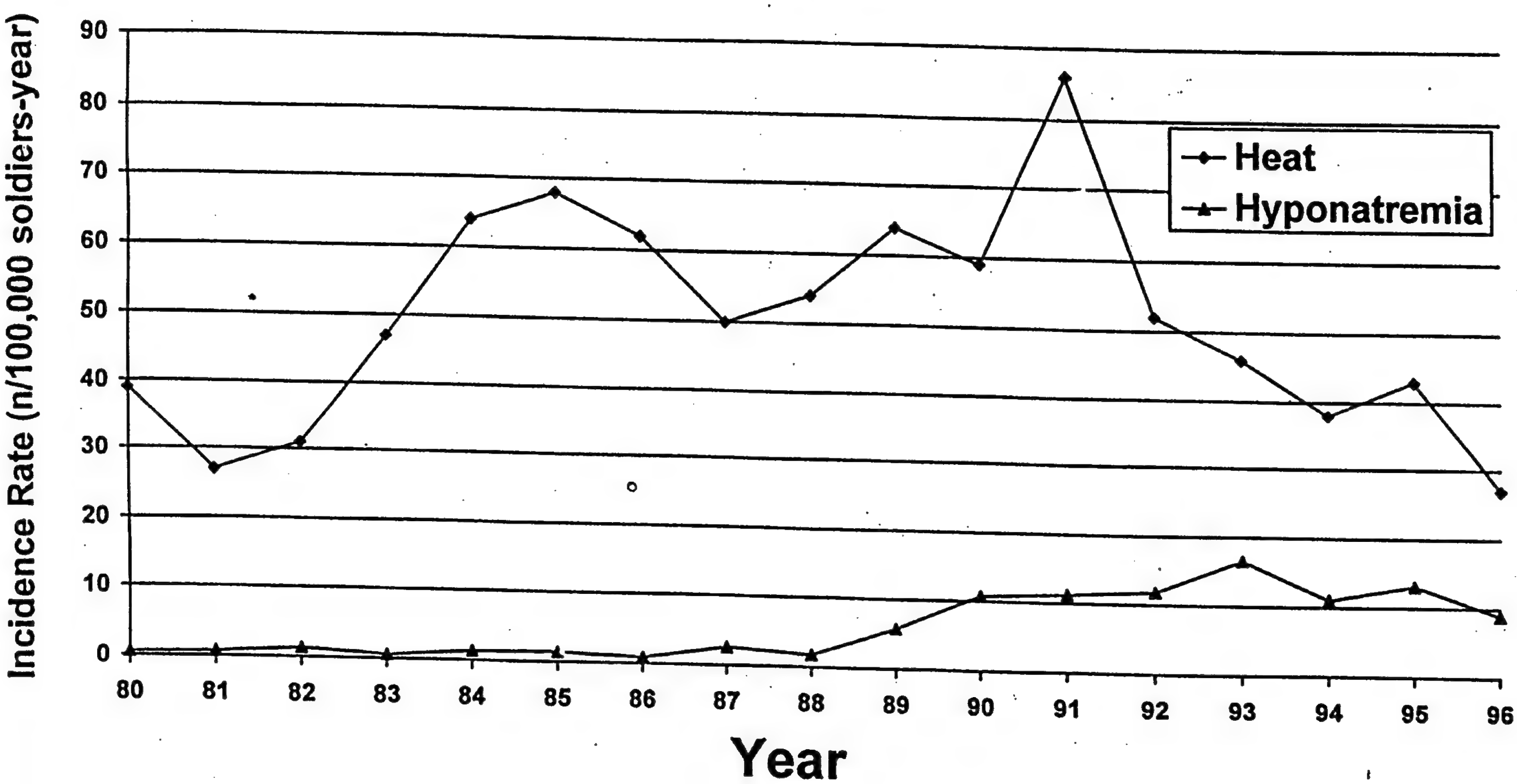


FIGURE. 4

APPENDIX D

MEMORANDUM FOR COMMANDER, MARTIN ARMY COMMUNITY HOSPITAL
SUBJECT: EPICON: OVERHYDRATION WITH SECONDARY HYPONATREMIA AT FT. BENNING, GA: FINAL REPORT

MCHB-DC-EDE 29 August 1997

MEMORANDUM FOR CDR, MARTIN ARMY HOSPITAL, FT BENNING GA

SUBJECT: EPICON: Overhydration with Secondary Hyponatremia at Ft. Benning, GA: Final Report

1. Background.

a. In late July 1997, Martin Army Community Hospital (MACH) notified the US Army Center for Health Promotion and Preventive Medicine (USACHPPM) that 5 cases, one terminating fatally, of apparent hyponatremia in trainees had been identified during the month. An epidemiological consultation (EPICON) was requested to assist in the investigation of these cases.

b. MAJ William Corr, Preventive Medicine Officer, Ft Benning, recommended immediate water policy changes to reduce the number of cases, and developed and initiated a study protocol to assess the prevalence and risk factors associated with exertional hyponatremia and fluid consumption in basic trainees. The USACHPPM, US Army Research Institute of Environmental Medicine (USARIEM), and Nephrology Department, Madigan Army Medical Center initially facilitated MAJ Corr's efforts with epidemiologic, physiologic, and clinical expertise.

c. An EPICON was conducted 27-29 August to further assist MAJ Corr's investigation, refine the problem definition, and provide recommendations for continued research and, potentially, water policy changes.

2. Historical.

a. The ICD-9 code for "hyposmolality and/or hyponatremia" is 276.1. For surveillance purposes a case was defined as: 1) an only and/or primary diagnosis of 276.1, 2) any diagnosis of 276.1 plus any heat associated diagnosis (ICD-9 code 992.x), or 3) any diagnosis 276.1 plus any diagnosis of "fluid overload" (ICD-9 code 276.6)

b. The IPDS (1989-1996) provided 125 hospitalizations which met one or more of the above criteria. The average number of cases per year was 15.6 (range 10-26). Males accounted for 84.8% of cases. The majority of cases occured from June through August. Forty percent of the cases occurred at Ft Benning.

3. Findings.

a. All 11 hyponatremia cases at Ft Benning for 1996-1997 were reviewed. These cases were characterized by being white, male, occurring early in the training cycle, having a large oral

water intake, mental status changes, nausea, and vomiting. All occurred in a setting of heat stress and moderate to heavy activity.

b. Only 2 of the cases demonstrated an elevated rectal temperature, and both of these cases had primary diagnoses of infectious etiology.

c. The average serum sodium was 121 mOsm (range 116-133). Serum and urine osmolality data was incomplete on 10 of the cases.

d. The training cadre at Ft Benning have been aggressive and thorough in implementing army water replacement doctrine. Unfortunately, this doctrine, for heat category 5 conditions, is inappropriate as it overwhelms the body's ability to process such a large volume of water and maintain electrolyte balance.

e. Policy Memorandum 97-14, Treatment, Evacuation of Heat Casualties, which increases early detection and monitoring of heat injury cases, and the volume of water these soldiers consume over time, has been implemented on post.

4. Conclusions.

a. Eleven cases of hyponatremia in a setting of heat stress and heavy activity in previously healthy individuals have occurred at Ft Benning during 1996-97.

b. All cases have been associated with a large oral water intake.

c. The training cadre on post are to be applauded for their diligent efforts to reduce heat injuries among trainees.

d. The current army doctrine for maximal fluid replacement per hour needs revision.

e. Policy Memorandum 97-14 Treatment, Evacuation of Heat Casualties was reviewed and is an appropriate interim policy with changes noted in para 5(d).

f. MAJ Corr's investigation is proceeding as planned.

5. Recommendations.

a. The Preventive Medicine Service, MACH and the USACHPPM should develop a questionnaire for use by the Emergency Medicine Department to capture demographic and risk

factor data on each case. (Case definition: a soldier with a serum sodium <130mOsm in a setting of heat stress or heavy activity in a previously healthy individual).

b. Fluid replacement requirement doctrine for the army needs to be reviewed and corrected by USARIEM and the Nephrology Department, MAMC.

c. Once new fluid replacement doctrine is established, the USARIEM should conduct study protocols to validate the doctrine at Ft. Benning.

d. Policy Memorandum 97-14 should have the following changes:

1) para 3g(1) should have the addition "and/or 2 episodes of emesis."

2) para 3g(3) should be changed to read "after 1 hour of hydration."

e. Continuing research efforts should include the elucidation of environmental, demographic, and physiologic factors which bear on the development of hyperhydration and hyponatremia in military trainees in a hot climate.

f. The USACHPPM, USARIEM, and Nephrology Department, MAMC should continue to assist MAJ Corr in his investigation.

6. Point of contact for this message is the undersigned at (410)671-1054; DSN 584-1054.

STEPHEN C.CRAIG
LTC, MC
EPICON Team Chief

EPICON Team:
COL Howard Cushner
Dr. John Brundage
Dr. Michael Sawka
Dr. Joseph Knapik
CPT Scott Montain

APPENDIX E

BRIEFINGS PRESENTED AT THE EPICON TEAM MEEING 27-29 AUGUST 1997

"Exertional hyponatremia"
Fort Benning, Georgia
28 August 1997

"Hyponatremia" hospitalizations, US Army, 1989 – 1996

1. Background:

IPDS: discharge diagnoses (up to 8) for all hospitalizations in Army MTFs

ICD-9 code 276.1: "Hyposmolality and/or hyponatremia"

2. Surveillance case definition:

From 1989 - 1996, among active/reserve component soldiers (incl cadets), there **553** hospitalizations with any diagnosis of 276.1

"Probable" cases were defined as ~

-- One and only diagnosis = 276.1 : **14**
-- 1st ("primary") diagnosis = 276.1 : **61**
-- Any diagnosis = 276.1 *plus* any heat associated diagnosis (ICD-9 = 992.x) : **49**
-- Any diagnosis = 276.1 *plus* any diagnosis of "fluid overload" (ICD = 276.6) : **29**

3. Results:

125 hospitalizations met one or more of the above criteria and, thus, were considered "probable cases."

Presented by:
J. Brundage, MD, MPH
202-782-1350

"Exertional hyponatremia"
Fort Benning, Georgia
28 August 1997

"Hyponatremia" hospitalizations, US Army, 1989 – 1996

Encl 2

a. By year:

1989	10
1990	26
1991	13
1992	16
1993	18
1994	12
1995	19
1996	11

b. Gender:

Male:	106	(84.8 %)
Female:	19	(15.2 %)

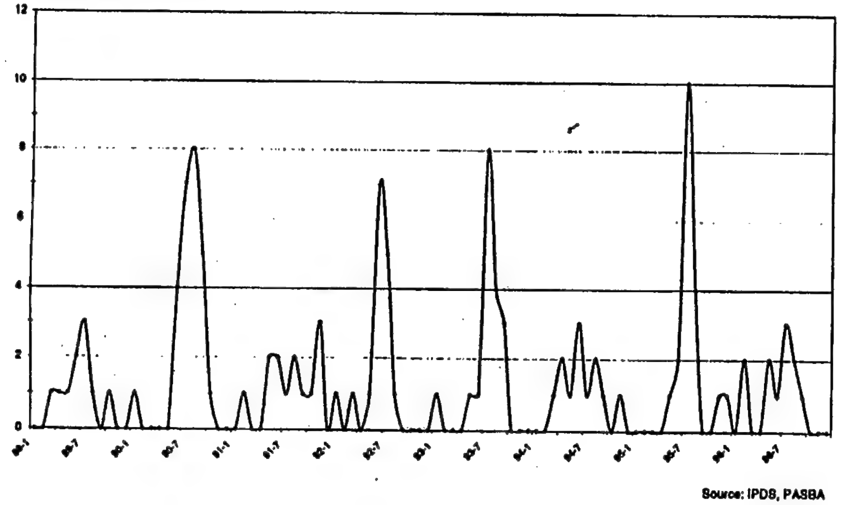
c. Race:

White	103	(82.4 %)
Black	13	(10.4 %)
Asian/Pac	5	(4.0 %)
Other/unk	4	(3.2 %)

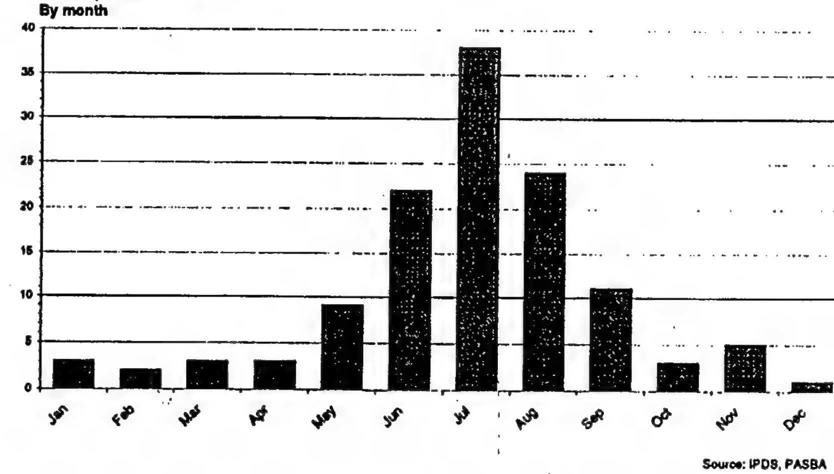
d. Status:

Active duty	81	(64.8 %)
Nat'l Guard	20	(16.0 %)
Reserve	11	(8.8 %)
"Recruit"	10	(8.0 %)
Cadet	3	(2.4 %)

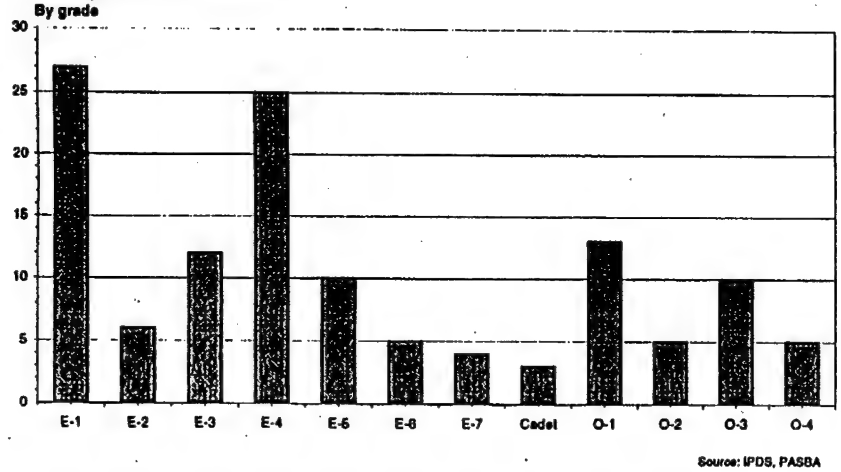
"Hyponatremia" hospitalizations
US Army, 1989 - 1996
By year, month



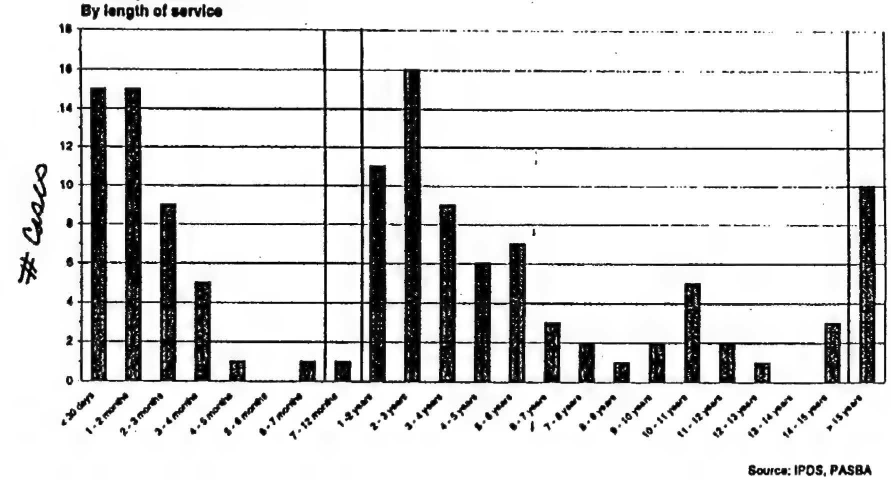
"Hyponatremia" hospitalizations
US Army, 1989 - 1996
By month



"Hyponatremia" hospitalizations
US Army, 1989 - 1996
By grade



"Hyponatremia" hospitalizations
US Army, 1989-1996
By length of service



Hospitalizations, "hyponatremia," US Army, 1989 – 1996
Source: IPDS, PASBA (* Fort Benning cases are shaded)

Year	Date	MTF	Age	Sex	Grade	Length Svc	Race	Diag1	Diag2	Diag3
1989	03/24/89	A1301	Y40	M	E7	Y19	N	2761	0449	7958_2
1989	04/30/89	A1341	Y26	F	E3	D21	C	2761	2768	2765
1989	05/25/89	A1501	Y19	M	E1	D06	C	2761	486	4610
1989	06/09/89	A1311	Y25	M	E6	Y05	C	9923	5849	2761
1989	06/10/89	A1311	Y27	F	E5	Y01	C	2766	2761	[illegible]
1989	07/08/89	A1211	Y19	M	E2	Y01	C	2761		
1989	07/10/89	A1001	Y21	M	O1	D27	C	2761	92310	3490
1989	07/10/89	A1001	Y21	M	O1	D27	C	2761	92310	3490
1989	08/09/89	A1401	Y38	F	O1	D14	C	2761	2769	2765
1989	10/06/89	A1601	Y34	M	E6	Y14	C	2761	1869	
1990	01/10/90	A1011	Y30	M	E5	Y11	C	2761	0340	V717
1990	06/07/90	A1331	Y21	F	E1	M03	C	5589	7919	2761
1990	06/20/90	A1031	Y32	M	O3	Y10	C	9923	34510	2761
1990	06/25/90	A1371	Y40	F	E4	Y05	C	9924	2761	2754
1990	06/30/90	A1431	Y18	M	E1	D10	C	2761	2766	7245
1990	07/10/90	A1311	[illegible]	M	E3	D20	C	9923	2761	[illegible]
1990	07/12/90	A1031	Y21	M	E4	Y03	C	2761		
1990	07/13/90	A1031	Y22	M	E4	Y04	C	9925	2761	
1990	07/13/90	A1031	Y25	M	E4	Y03	C	9929	2761	
1990	07/16/90	A1311	Y30	M	E5	Y06	C	9920	2765	[illegible]
1990	07/21/90	A1331	[illegible]	M	E1	D27	C	2930	2761	[illegible]
1990	07/30/90	A1311	[illegible]	M	E3	M04	N	9924	2765	[illegible]
1990	08/01/90	A1311	[illegible]	M	O1	Y10	C	2766	2761	[illegible]
1990	08/01/90	A1341	Y20	M	E1	M01	C	2761	2766	7803
1990	08/07/90	A1311	[illegible]	[illegible]	[illegible]	[illegible]	C	9925	2765	[illegible]
1990	08/08/90	A1401	Y33	F	O3	Y09	C	9925	2761	4240
1990	08/18/90	A1311	[illegible]	[illegible]	E4	Y02	C	9923	2765	[illegible]
1990	08/25/90	A1311	[illegible]	M	E1	D21	M	9925	2765	[illegible]
1990	08/25/90	A1311	[illegible]	M	[illegible]	D20	N	2761	2766	[illegible]
1990	08/29/90	A1241	Y30	F	E5	Y05	C	9923	2762	2768
1990	09/15/90	A1221	Y33	M	O3	Y10	C	9925	9945	2761
1990	09/23/90	A11D1		M	O2	ZZZ	C	2761		
1990	09/24/90	A1311	[illegible]	M	E1	M01	M	2765	5589	[illegible]
1990	09/24/90	A1311	Y32	M	O2	Y08	C	9920	2761	[illegible]
1990	09/24/90	A1311	Y19	M	E1	D23	C	9924	2761	[illegible]
1990	10/10/90	A1361	Y27	M	O2	Y05	C	2761	2989	
1991	02/25/91	A08J1	Y21	M	E4	Y03	C	2761		
1991	05/17/91	A1311	Y26	M	O3	Y05	C	9925	2761	2766
1991	05/25/91	A1311	Y29	M	O3	Y06	R	9925	2761	2766
1991	06/20/91	A1311	Y21	M	E3	Y01	C	2761	2766	3009
1991	06/28/91	A1411	Y27	M	E3	Y01	C	2761	7803	72889
1991	07/03/91	A1371	Y37	M	E7	Y17	C	9922	2761	2765
1991	08/01/91	A1211	Y26	M	E5	Y07	C	2761	2768	7889
1991	08/07/91	A0311	Y27	M	E5	Y05	C	2761	7803	
1991	09/26/91	A1341	Y20	M	E1	M02	N	2761	6869	
1991	10/10/91	A1311	Y19	M	E1	M02	C	9925	7803	3483
1991	11/10/91	A1331	Y17	M	E1	M01	C	9920	2761	2766
1991	11/15/91	A01K1	Y21	M	E4	Y02	N	2761	2512	
1991	11/23/91	A01K1	Y21	M	E4	Y03	C	2761		
1992	01/31/92	A01K1	Y20	M	E3	Y01	N	2761	7806	462
1992	03/24/92	A1031	Y34	M	O1	Y10	C	2761	2765	7803
1992	05/15/92	A1311	Y33	M	E5	Y02	C	2761	7803	2768
1992	06/09/92	A1311	Y25	M	O1	M01	C	2761	[illegible]	[illegible]
1992	06/09/92	A1371	Y23	M	E4	Y03	C	9925	2761	
1992	06/13/92	A1311	Y35	M	E5	Y02	C	7803	9920	2761
1992	06/13/92	A1311	Y25	F	E4	Y03	C	5589	2761	2766
1992	06/19/92	A1431	Y19	M	E4	Y02	C	2761	2766	
1992	06/24/92	A1031	Y26	M	E4	Y01	X	9923	2761	7800
1992	06/30/92	A1331	Y20	M	E2	D25	C	2761		
1992	07/05/92	A1311	Y26	M	E4	Y04	C	2761	3009	2768
1992	07/09/92	A1311	Y21	M	E3	M01	C	9925	4659	2761
1992	07/10/92	A1311	Y22	M	O1	M01	C	9921	2761	2766
1992	07/16/92	A1431	Y41	M	E7	Y18	C	2766	2761	
1992	07/31/92	A1371	Y20	M	E3	Y02	C	9928	2761	
1992	08/11/92	A1071	Y23	M	O2	Y06	C	2761		
1993	01/18/93	A13C1	Y38	M	E6	Y18	Z	9929	2761	
1993	05/16/93	A1371	Y45	F	O5	Y10	C	9920	2762	2768
1993	06/03/93	A1311	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1993	07/17/93	A1311	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1993	07/21/93	A1311	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1993	[illegible]	A1311	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1993	07/24/93	A1311	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1993	[illegible]	A1311	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1993	07/29/93	A1311	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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1993	07/30/93	A1311	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1993	08/03/93	A1331	Y19	M	E1	M01	C	2761	2752	2768
1993	08/06/93	A0341	Y28	F	E4	Y02	C	2761	2768	2752
1993	08/16/93	A1431	Y26	M	E1	M04	C	2766	2761	72982
1993	08/17/93	A1431	Y19	M	E1	M02	C	4660	0415	2766
1993	09/01/93	A1331	Y20	M	CD	Y02	N	2761	2766	9924
1993	09/08/93	A1311	[illegible]	M	[illegible]	M02	C	2761	[illegible]	[illegible]
1993	09/22/93	A1361	Y22	M	O1	Y01	C	9929	2761	72889
1994	03/16/94	A1311	Y22	M	E3	M01	C	2766	2761	[illegible]
1994	04/21/94	A1311	Y19	M	E1	Y01	N	9922	2761	2766
1994	04/30/94	A1311	Y22	M	E1	M01	[illegible]	9925	2761	[illegible]
1994	05/12/94	A0121	Y48	M	O6	Y19	C	2761	E9426	2769
1994	06/17/94	A1231	Y19	F	E1	Y01	C	2761	2768	2754
1994	06/19/94	A1231	Y24	M	E4	Y02	C	2761		
1994	06/25/94	A1311	Y20	M	E1	D02	C	2761	2766	[illegible]
1994	07/20/94	A1071	Y21	M	CD	Y01	N	2761	2766	
1994	08/12/94	A1401	Y32	F	O3	Y12	C	2761		
1994	08/26/94	A0341	Y40	F	O4	Y16	C	5849	5119	2766
1994	09/14/94	A1231	Y52	F	O5	Y23	C	9925	2766	2761
1994	11/23/94	A0611	Y33	M	E6	Y15	N	2761	25000	49390
1995	05/10/95	A1311	Y22	M	E4	M01	C	9925	4659	2766
1995	06/16/95	A13C1	Y21	M	E4	Y02	C	2766	2761	4871
1995	06/16/95	A13C1	Y36	F	O4	Y14	C	07999	2765	2766
1995	07/02/95	A1341	Y27	M	E4	Y08	C	2761	7803	7809
1995	07/11/95	A1301	Y24	M	O3	Y06	C	2761	2766	[illegible]
1995	07/13/95	A1231	Y25	M	O1	Y04	C	9925	2766	2761
1995	07/15/95	A1231	Y18	M	E1	M07	C	2761	2765	
1995	07/16/95	A1311	Y22	[illegible]	E5	Y02	C	9924	2761	[illegible]
1995	[illegible]	A1311	[illegible]	[illegible]	[illegible]	[illegible]	C	[illegible]	[illegible]	[illegible]
1995	[illegible]	A1311	[illegible]	[illegible]	[illegible]	[illegible]	C	9920	2761	[illegible]
1995	07/25/95	A1231	Y18	F	E1	M02	C	2761	7803	2536
1995	07/27/95	A1331	Y18	M	E1	D14	C	2766	2761	2754
1995	07/29/95	A1071	Y19	M	CD	M02	C	2761		
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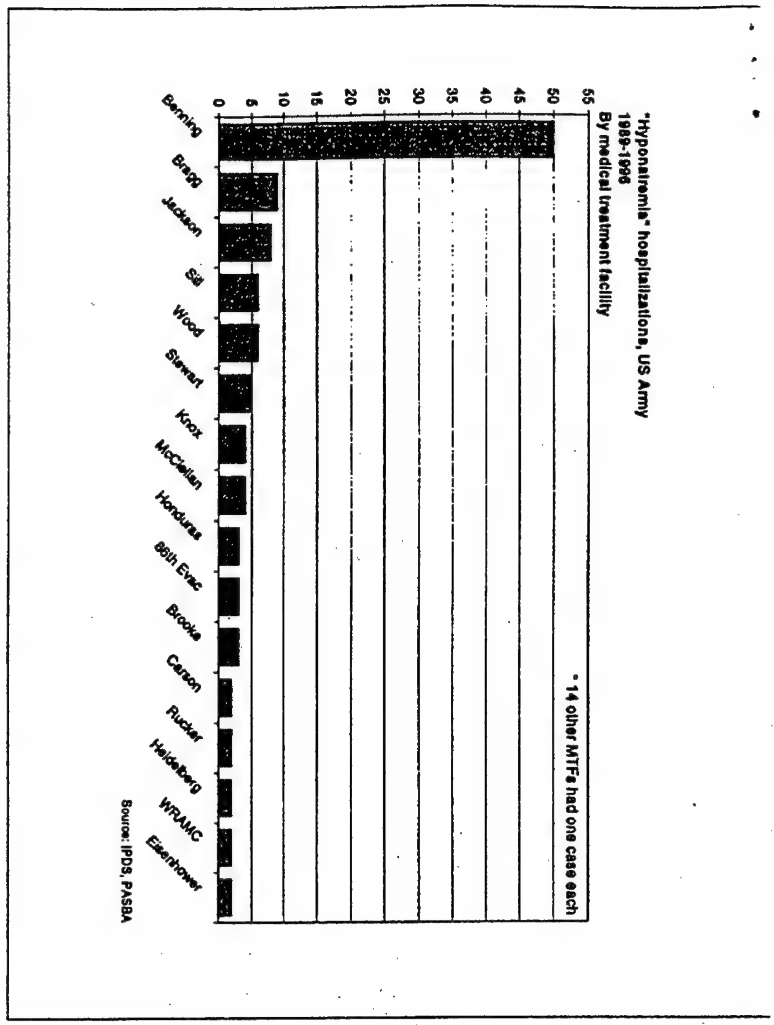
1995	[illegible]	A1311	Y01	F	E1	D14	C	9920	2765	[illegible]
1995	11/16/95	A1031		M	E2	Y02	C	2761	7809	78701
1995	12/12/95	N61564		M	E4	Y02	N	2761		
1996	02/05/96	A1331		M	E4	Y01	C	2761	7803	
1996	02/18/96	N61564		F	O3	Y03	C	2761	2512	
1996	05/06/96	A1031		M	O2	Y04	C	2761	2766	
1996	05/12/96	A1321		F	E4	Y02	M	2761	53500	8449
1996	06/21/96	A1311		[illegible]	[illegible]	M03	C	2761	2766	[illegible]
1996	07/04/96	A1431		M	E1	Y03	C	9921	2766	2761
1996	07/11/96	A1311		M	O1	M03	C	2761	2765	
1996	07/22/96	A1031		M	E5	Y05	X	2761	7803	71991
1996	08/01/96	A1311		M	O1	Y02	C	2761	4659	[illegible]
1996	08/29/96	A1311		M	O3	Y08	C	2766	2761	[illegible]
1996	09/29/96	A1301		F	E5	Y04	N	2761	2769	

"Hyponatremia"
Fort Benning, Georgia
28 August 1997

"Hyponatremia"
Fort Benning, Georgia
28 August 1997

"Hyponatremia"
Fort Benning, Georgia
28 August 1997



"Hyponatremia" hospitalizations, US Army
1989-1996
By medical treatment facility
0
5
10
15
20
25
30
35
40
45
50
55
Benning
Bragg
Jackson
Sill
Wood
Stewart
Knox
McClellan
Honduras
86th Evac
Brooke
Carson
Rucker
Heidelberg
WRAMC
Eisenhower
* 14 other MTFs had one case each
Source: IPDS, PASBA

EPIDEMIOLOGICAL INFORMATION ON EXERTIONAL HEAT ILLNESS AND HYPONATREMIA

Dr Joseph Knapik
U.S. Army Center for Health Promotion and Preventive Medicine
Aberdeen Proving Ground, MD 21040

ENCL 3

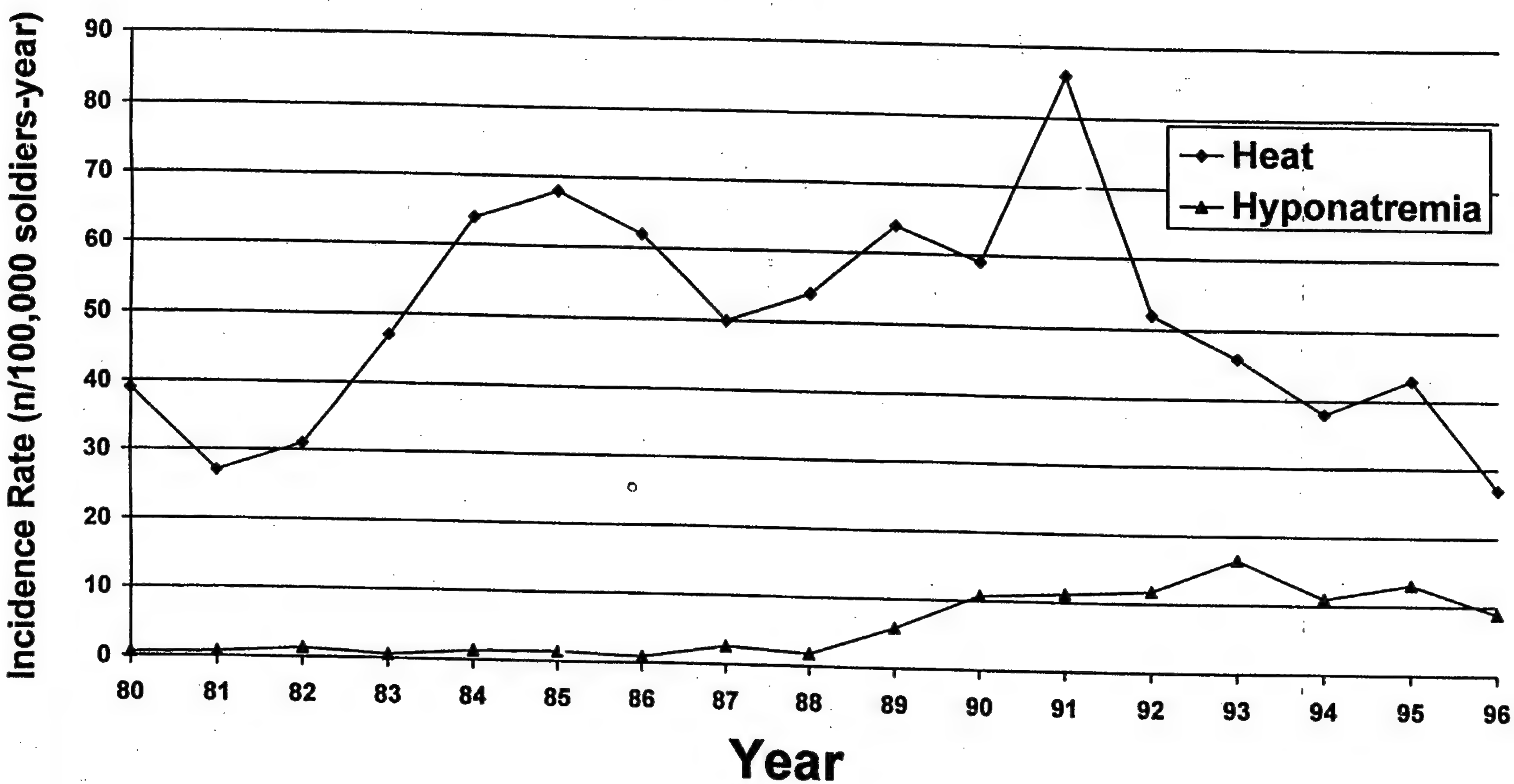
Exertional Heat Illness (EHI) in 12 Weeks of Marine Recruit Training at Parris Island, NC

STUDY	Years	Sample Size	EHI Cases	EHI Incidence (cases/1000)	EHI Hospitalization Incidence (Cases/1000)	Summer EHI Incidence [May-Sept] (Cases/1000)
Gardner et al., 1996	1988-1992 (5 years)	88,000	528	6.0	0.66	
Kark et al., 1996	1982-1991 (10 years)	216,615	1454	6.7	0.74	~20

Exertional Heat Illness Cases with Serum Na at Naval Hospital, Beaufort, SC, 1980-1994 (Sample n=1043) (From Dr Bruce Wenger)

Serum Na	Cases	Incidence (Cases/100)
<130	7	2.2
<135	24	7.4
>145	218	20.9

Hospitalizations due to Excess Heat/ Insulation and Hyposmolality/ Hyponatremia in Men in the Army 1980-1996



Hyponatremia (HN) in Various Active Groups

Study	Population	Sample Size	"Hyponatremia" Definition	Incidence of HN (cases/100)	Estimated Incidence of HN in population (cases/100)	Fluid Intake (liters)
Hiller et al., 1985	Triathletes in IRONMAN with blood withdrawn	64	"Abnormally low post-race Na or Cl"	29		
Hiller et al., 1986	Triathletes in IRONMAN with blood withdrawn	136	"Hyponatremia"	20	1.5	
Noakes et al., 1990	Collapsed finishers in 90-km Comrades Unltramarathon	315	Serum Na <130 mmoles/l	9	0.3	
Irving et al., 1991	Collapsed runners in 88-km Comrades Untramarathon	~300	Serum Na <130 mmoles/l	~3		12.5 ± 3.6 (est in 10 h)
Armstrong et al., 1993	Subjects in research study (8 h of intermittent exercise)	10	Serum Na <130 mEq/l	10		10(N=1) 5+2(N=9) (fluid balance: N=1:+2.81 N=9:-1.21)

TABLE 1. Estimated water and sodium chloride balance in four athletes who developed water intoxication during prolonged exercise.

1 Case No.	2 Body Wt. (kg)	3 Exercise Duration (h:min)	4 Post-Race Serum Sodium Concentration (mmol · l^{-1})	5 Predicted Sodium Chloride Losses to Explain Degree of Hyponatremia (mmol)	6 Predicted Excess Fluid Intake to Explain Hyponatremia (l)	7 Estimated Fluid Intake (l)	8 Predicted Total Sweat Loss (l)	9 Estimated Excess Fluid Intake (l)*	10 Estimated Total Sodium Chloride Loss in Sweat** (mmol)	11 Estimated Sodium Chloride Intake Required to Correct the Hyponatremia*** (mmol)	12 Estimated Post-Race Serum Sodium Concentration (mmol · l^{-1})****
1 (E.S.)†	49	±7:00	115	676	5.4	6	4††	2	240	722	122
2 (R.G.)†	75	10:10	118	900	7.6	12	9††	3	540	960	118
3 (P.B.)†	73	±9:00	124	1007	8.8	10	5	5†††	300	683	118
4 (M.H.)	57	9:56	125	445	3.6	8	3½	4½†††	210	503	117

All calculations were made using conventional calculations (Ref. 19) and are subject to the many assumptions that were necessary for their computation.

† Although exact environmental data for the 1981 and 1982 Comrades Marathons (Cases 1–3) are not available, data from the 1983 and 1984 races indicate that the average WBGT during this race ranges between 15 and 23°C. Environmental conditions during the Durban Triathlon (Case 4) were similar.

†† Estimated on basis of 70-kg man losing 9 l of sweat during the 90-km Comrades Marathon and 50-kg woman losing 4 l in 70 km (Ref. 7).

††† Estimated on basis of excess fluid losses during period of hospitalization (Case 3) and body weight gain during exercise (Case 4). See text.

* Calculated as estimated fluid intake (Column 7) − predicted total sweat loss (Column 8).

** Calculated on the assumption that the average sweat sodium content is 60 mmol · l^{-1} (Ref. 3).

*** Calculated on the basis of estimated total body water at the end of the race (0.6 × body weight in kg (Column 2) + estimated excess fluid intake (Column 9) and the measured post-race serum sodium chloride concentration (Column 4).

**** Calculated on the basis of estimated excess fluid intake (Column 9) and estimated sweat sodium (chloride) losses (Column 10).

Noakes, Med Sci Sports Exerc 17:370-375, 1985

Case Studies of Hyponatremia Associated with "Over Hydration" in Active Subjects Admitted to Emergency Rooms

Study	Case	Estimated Fluid Intake	Serum Na	Symptoms/sign/discharge
Surgenor and Uphold, 1991	57-yr old male triathlete, completed 30 of 100-mile race	7.5 l Kool-Aid at race; 1-1.5 l Kool-Aid post running	119 mEq/l on admission; 111 mEq/l 3 h later	Dizzy; slurred, unintelligible speech, collapsed. CT scan neg; discharged 3 days
Frizzel et al., 1986	24-yr old male medical student, 45 yr old male physician; both running AMJA ultramarathon	24 yr old: 20 l 45 yr old: 24 l	24 yr old: 123 mEq/l on admission 45 yr old: 118 mEq/l on admission	24 yr old: semiawake, disoriented, inappropriate responses to verbal commands, grand mal; discharged 5 days 45 yr old: disoriented, confused, slurred speech, unpurposeful movements ; discharged 8 h
Young et al., 1987	21 yr old male student running marathon	Water at every of 16 water stops; 2 liters post-race; 2 liters in emergency room	123 mEq/l on admission	incoherent, agitated, delirium; pulmonary edema, CT scan showed generalized cerebral edema (36 h later Ct scan normal); discharged 7 days

Klonoff and Jurow, JAMA
265: 84-85, 1991

ases of Voluntary Water Intoxication Without Chronic Psychiatric or Neurologic Disease

Source, y	Patient No./Sex/Age, y	Water Intake: Volume, L	Water Intake: Duration, h	Serum Sodium, mmol/L	Clinical Setting	Duration Until Recovery, h
ckering and Hogan,[17] 1971	1/M/9	10-15	48	123	Toothache pain	12
iedman et al,[18] 1983	2/M/28	30-40 glasses	5	117	Urethral stricture	19
nastassiades et al,[19] 1983	3/F/40	5	2	111	Bleach ingestion	4 d*
hristenson and Scott,[20] 1985	4/F/79	1.5-2	Hours	122	Pelvic ultrasound	24
ott and Marcus,[21] 1985	5/F/21	30 glasses	Minutes	127	Pelvic ultrasound	24
psky and Zabak,[22] 1987	6/F/64	1.35	2	123	Pelvic ultrasound	14
hapira et al,[23] 1988	7/F/80	4	Hours	119	Abdominal ultrasound	24
esent study, 1991	8/F/40	3	3	121	Urine drug test	24

*Patient died.

Encl 4

Heat Stress & Hydration

CPT Scott J. Montain & Dr. Michael N. Sawka
U.S. Army Research Institute
of Environmental Medicine
Natick, MA

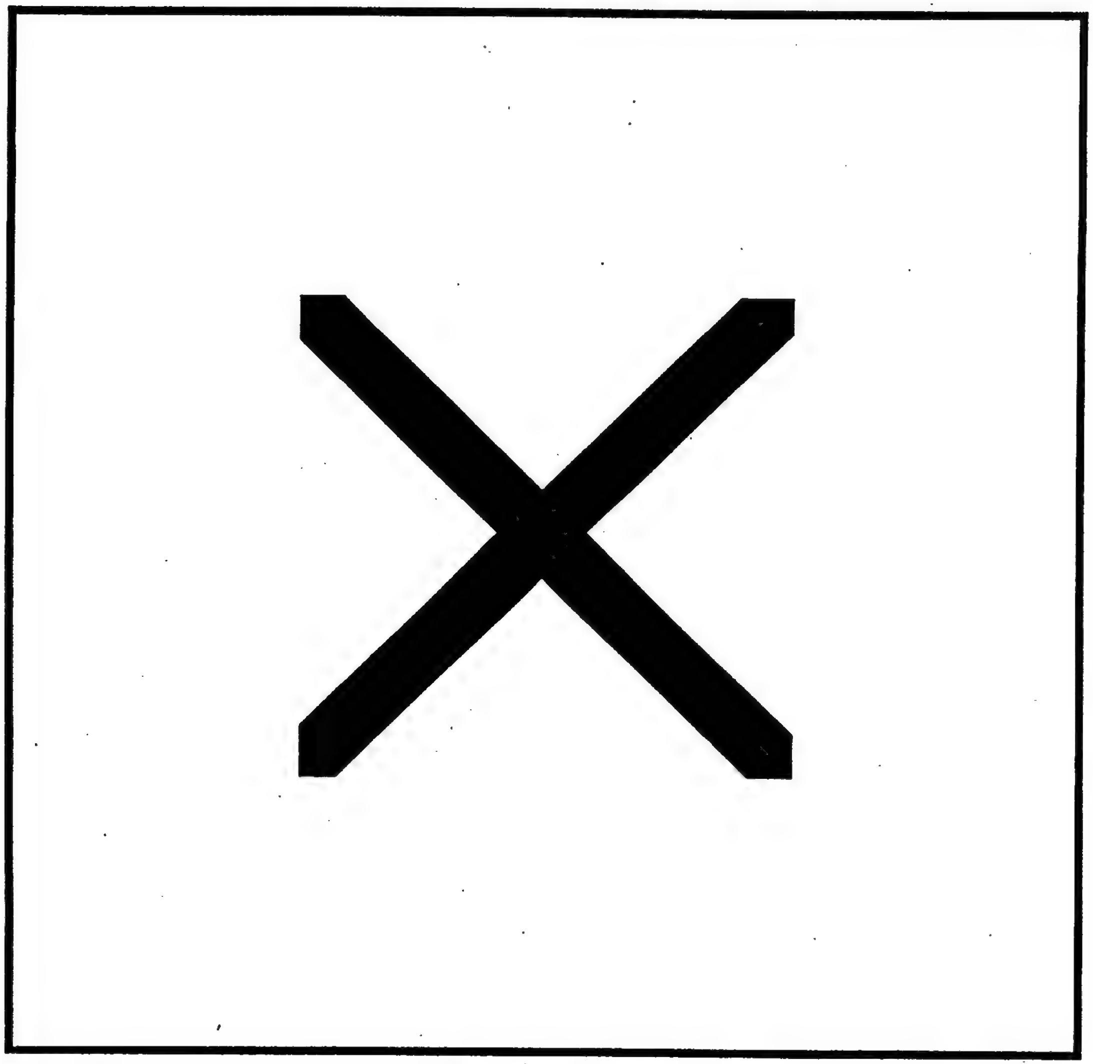
Thermal & Mountain Medicine Division, USARIEM

Outline

- Fluid Balance
- Dehydration Adverse Effects
- Hyperhydration Calculations
- Rehydration Guidelines
- Other Issues

Thermal & Mountain Medicine Division, USARIEM

Daily Fluid Balance



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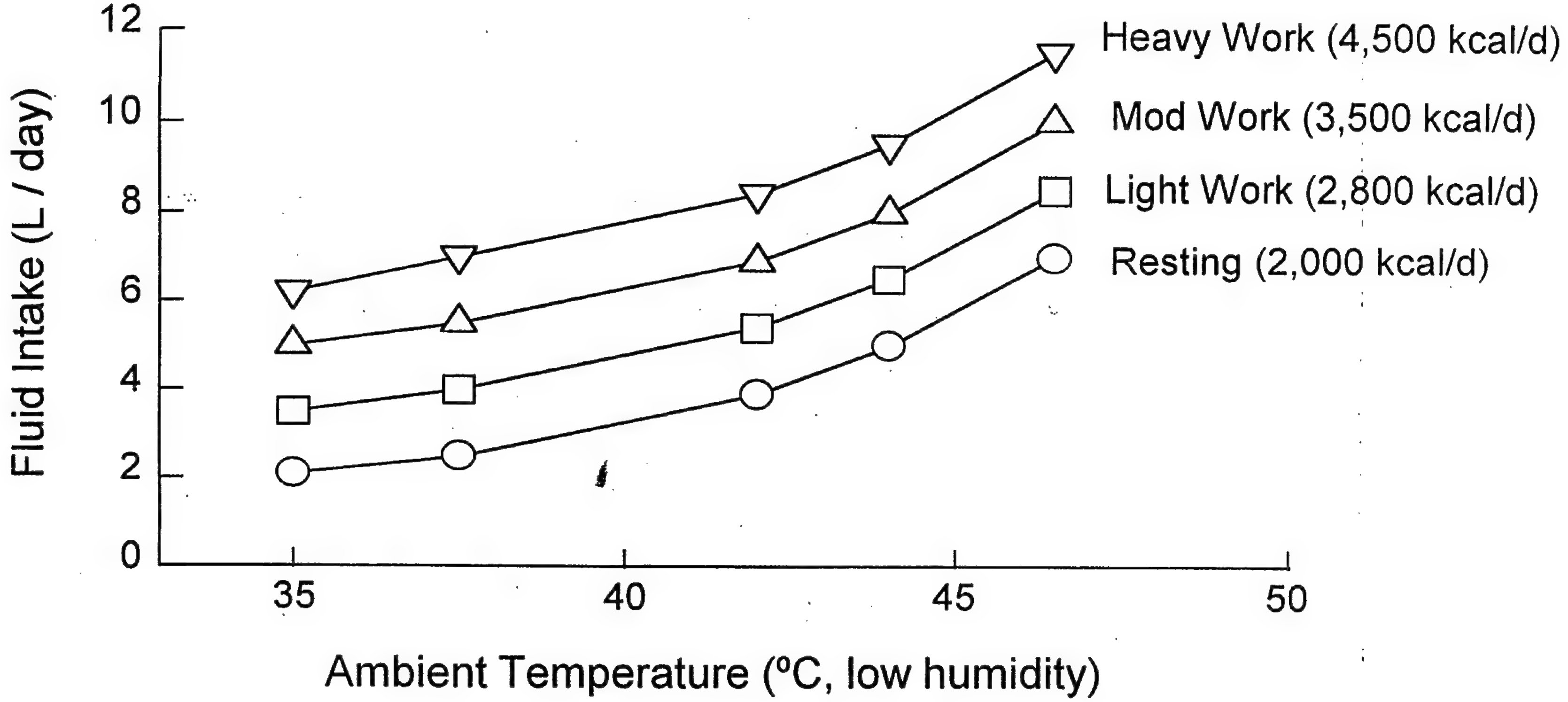
Climate & Exercise Intensity Effect on Daily Fluid Requirements



Nelson et al. Project # 2-6 1943

Thermal & Mountain Medicine Division, USARIEM

X5320

Fluid Balance Facts

- Sweating rates for military operations
  - « Range from 2 to 35 ml / min (0.12 to 2.1 L/h)
  - « Highly variable between conditions & persons
- Gastric emptying rates
  - « Average maximal rate ~ 20 ml / min (1.2 L/h)
  - « Highly variable between conditions & persons
  - « Reduced (25%) by heat stress & exercise intensity
  - « Full stomach empties faster
- Intestinal absorption rates
  - « Maximal rates unknown ~ 25% lower in heat or hi ex
  - « Exceeds gastric emptying rates
- Urine output: average maximal rate
  - @ Rest ~10 -12 ml / min (0.7 L/h)
  - @ Exercise ~ 3 ml / min (0.2 L/h)

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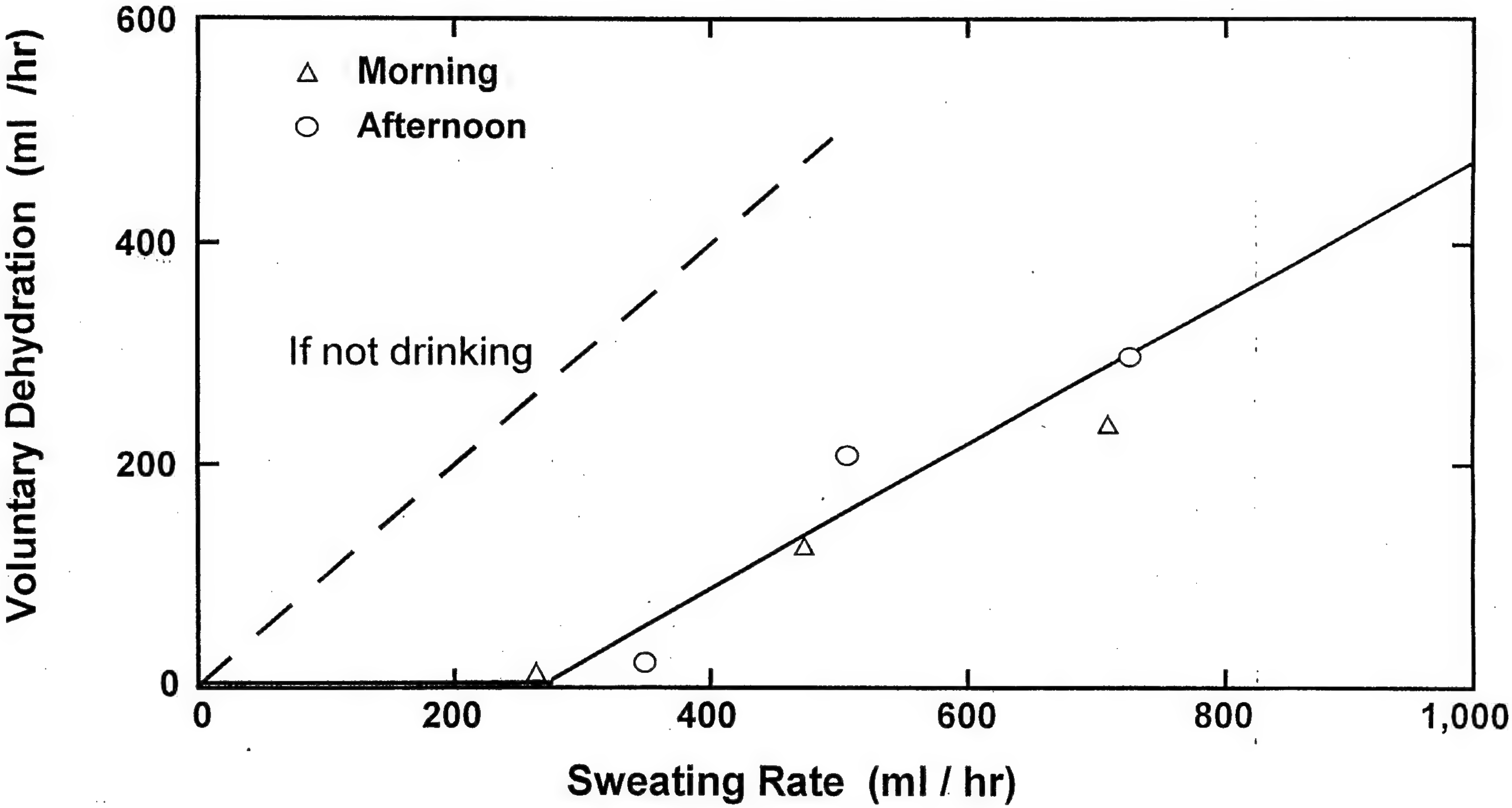
Sweating Rate & Voluntary Dehydration



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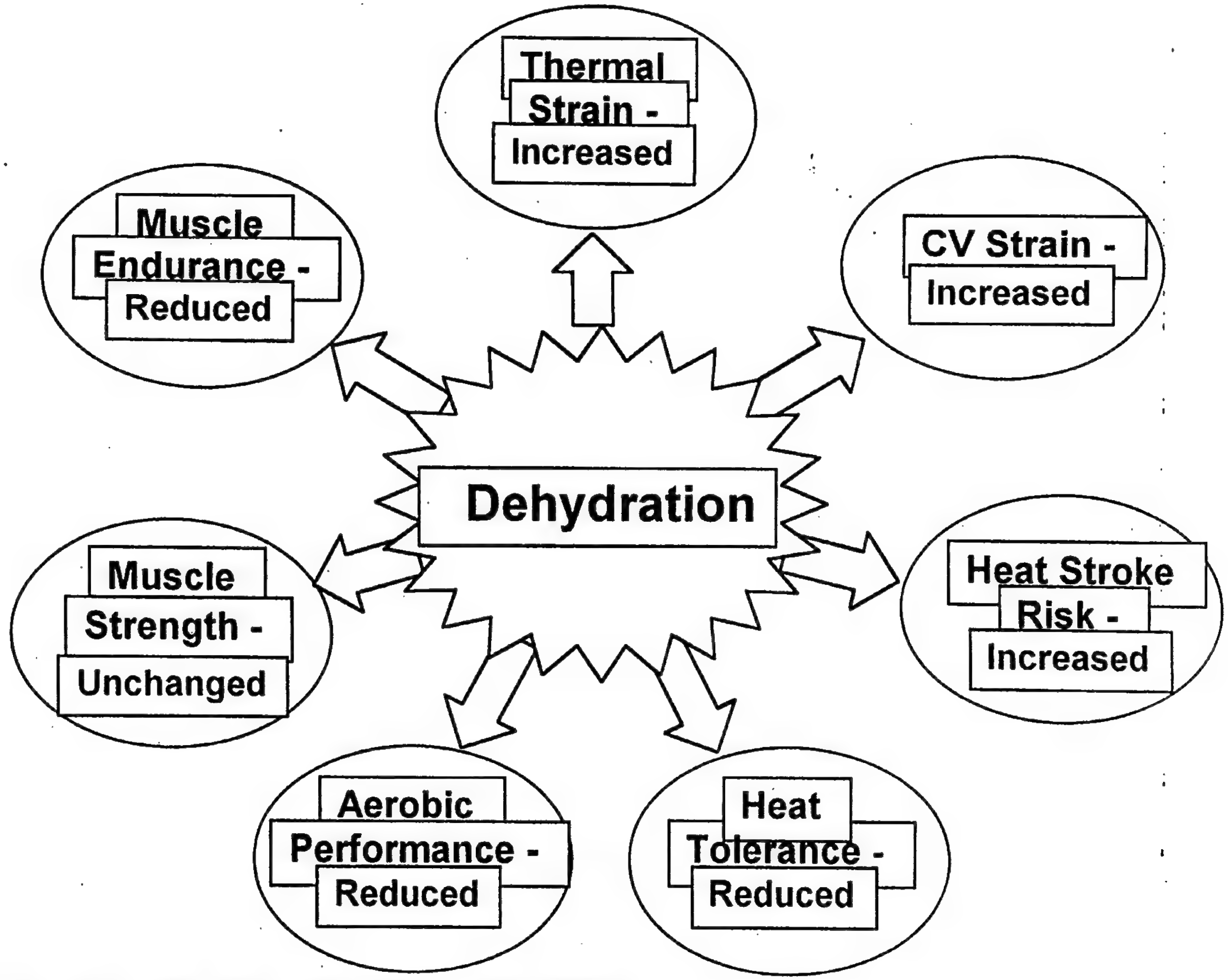
Dehydration Effects



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Symptoms From Dehydration In The Heat

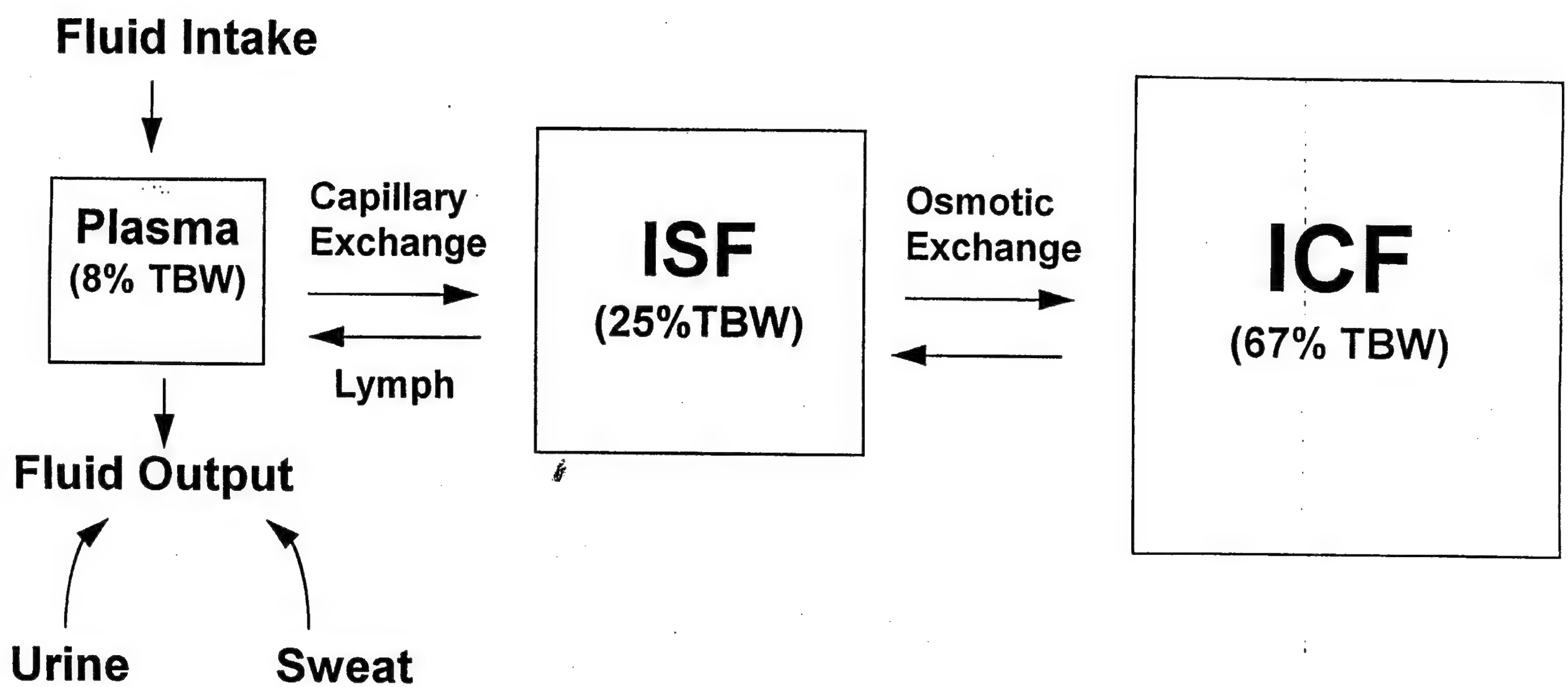
Body Water Loss

1-5% BWL	6-10% BWL	11-20% BWL
Thirst	Dizziness	Delirium
Vague discomfort	Headache	Spasticity
Economy of movement	Dyspnea	Swollen tongue
Anorexia	Tingling in limbs	Inability to swallow
Flushed skin	Absence of salivation	Deafness
Impatience	Cyanosis	Dim vision
Sleepiness	Indistinct speech	Shriveled skin
Increased pulse rate	Inability to walk	Painful micturition
Increased rectal temp.		Numb skin
Nausea		Anuria

Adolph & Associates, Physiol. Man in Desert, 1947

Thermal & Mountain Medicine Division, USARIEM

Body Water Volumes & Exchange



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Hyperhydration Calculations - 1

- Total Body Water (TBW) 60% of body weight
- Extracellular Fluid (ECF) 20% of body weight
- 70 kg soldier has:
- 70 kg x 0.60 = <u>42 L TBW</u>
  70 kg x 0.20 = <u>14 L ECF</u>
- Serum sodium is <u>140 mEq/L</u>
- Extracellular sodium is:

  14 L x 140 mEq/L = <u>1960 mEq</u>

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Hyperhydration Calculations - 2
(Replace Water with No Sweat Sodium Loss)

- To dilute serum sodium from 140 to 125 mEq / L:
  1960 mEq ÷ 125 mEq = 15.7 L ECF
- To maintain osmotic equilibrium , volume of ECF & TBW must increase in proportion
-
- Final TBW ÷ 42 L = 15.7 L ÷ 14 L = <u>47.1 L TBW</u>
-
- 47.1 L - 42 L = <u>5.1 L increase TBW</u>

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Hyperhydration Calculations - 3

(Sweat Sodium Loss)

- Sweat sodium concentration (5 - 60 mEq / L)
- If assume heat acclimated soldier secretes 6 L of sweat @ 25 mEq / L = 150 mEq sodium loss, & ECF sodium drops to 1810 mEq *(1960 - 150 mEq)*
- If assume that 6 L of water is consumed & retained so that TBW remains unchanged
- Serum sodium will decrease to <u>136.4 mEq / L</u>

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Hyperhydration Calculations - 4
(New Serum Sodium Calculation)

- To maintain osmotic balance, osmolality decreases in all fluid compartments by the same amount, corresponding to a decrease in serum sodium of 3.6 mEq/ L

  150 mEq *(sweat sodium loss)* ÷ 42 L TBW = 3.6 mEq / L
  140 mEq / L - 3.6 mEq / L = 136.4 mEq / L

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Hyperhydration Calculations - 5

(Replace Water with Sweat Sodium Loss)

- How much must this soldier overdrink to lower serum sodium from 136 to 125 mEq / L?
- To maintain osmotic equilibrium, volume of ECF & TBW must increase in proportion
- Final TBW ÷ 42 L = 136 ÷ 125 mEq / L
  - « 45.7 L TBW
  - « 45.7 L - 42 L = 3.7 L increase TBW

Thermal & Mountain Medicine Division, USARIEM

GE Beverage Facts

- **Glucose electrolyte beverages** (optimal formulation)
  - « 20 - 30 mEq / L sodium
  - « 2 - 5 mEq / L potassium
  - « Chloride as only anion
  - « 5% - 10 % CHO
- **Military use merited** (National Academy of Sciences, 1994)
  - « Conditions of high sweat & electrolyte losses
  - « During heavy work to maintain blood glucose
  - « Rapid rehydration after exercise
- **GE beverages usually same as water never worse**

Thermal & Mountain Medicine Division, USARIEM

Hyperhydration Calculations - 6
(Replace GE Beverage with Sweat Sodium Loss)

- This soldier will drink 9.7 L of GE beverage instead of water *(6.0 L sweat loss & 3.7 L overhydration)*
- The GE beverage (@ 25 mEq / L sodium) adds 242 mEq (9.7 L x 25 mEq / L) of sodium
- TBW will still be 45.7 L, but osmolality will be higher by <u>5 mEq / L</u> (242 mEq ÷ 45.7 L = 5)
- Serum sodium will be <u>130 mEq / L</u>

Rehydration Guidelines

- Fluid replacement should match sweat losses
- Kidneys will increase urine volume to compensate for overdrinking but may not be able to offset high rates of intake
- Overhydration of up to 1.8 L water is tolerated during rest & exercise - heat stress
- Peak fluid replacement rates ~1.2 - 1.5 L / h
- Remaining sweat deficits should be replaced during rest
- Eating provides missing solute and promotes fluid intake
- Meals are key to sustain fluid & electrolyte balance

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Rehydration Guidelines Recommendations

- Fluid replacement volumes specific to heat stress, activity & clothing levels
- Solute Replacement: GE beverage / snacks
- Awareness of drinking limits
- Awareness of urine volume & color
- If not recovered by 1- 2 L & cooling then normal saline *i.v.*
- *Heat Stress & dehydration primary problem*

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Other Issues

- Level vs rapidity of hyponatremia
- "One rehydration doctrine fits all"
- Electrolyte replacement?
- Normal variation for serum sodium on given doctrine
- Standardized guidance for treatment

APPENDIX F

RILEY CARD

RILEY CARD / Battle Buddy Initial When Soldier Drinks Complete Canteen

	S	M	T	W	T	F	S
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RILEY CARD / Battle Buddy Initial When Soldier Drinks Complete Canteen

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RILEY CARD / Battle Buddy Initial When Soldier Drinks Complete Canteen

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RILEY CARD / Battle Buddy Initial When Soldier Drinks Complete Canteen

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RILEY CARD / Battle Buddy Initial When Soldier Drinks Complete Canteen

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RILEY CARD / Battle Buddy Initial When Soldier Drinks Complete Canteen

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Encl 5

APPENDIX G

SUGGESTED MOTIFICATIONS TO ARMY FLUID REPLACEMENT GUIDELINES (1997)

MCMR-UE-TMD (70) 29 September 1997

MEMORANDUM FOR Commander, Martin Army Hospital, Fort Benning, GA 31905

SUBJECT: Fluid Replacement Guidelines for Training in Hot Weather

1. Reference Epidemiology Consultation at Fort Benning, GA 28-29 August 97 to investigate the incidences of clinical hyponatremia consequent to basic training activities.

2. At the request of the EPICON team and the Commander, Martin Army Hospital at Ft. Benning, GA, USARIEM has revised the water replacement guidelines for hot weather training. The changes proposed should minimize the likelihood of problems either from dehydration or water intoxication. The revised table is enclosed.

3. The procedures performed to generate the table are summarized below:

a. Estimated sweating rates were calculated using the USARIEM Heat Strain Model. Input variables and assumptions were: average size soldier performing easy (250 Watts, 3.5 kcal/min), moderate (425 Watts, 6 kcal/min) and hard (600 Watts, 8.6 kcal/min) military physical activities under ambient temperatures ranging from 70 to 110°F and 20 to 100% relative humidity during both full sun and full shade conditions. Wind speed for all calculations was kept constant at 2.5 mph. The uniform was the BDU, Hot weather.

b. The matrix was then collapsed by placing each weather condition in the appropriate WBGT index and averaging the sweating responses (Tglobe was estimated by adding +27°F to ambient temperature for full sun and +0°F for shade conditions).

c. The fluid replacement table was then compared to another model (SCENARIO) which estimates sweating rates during exercise in hot weather conditions. The results of the second model generally verified the outputs of the USARIEM Heat Strain Model. However, in some cases the estimated sweating rates and temperature responses were less than the USARIEM Heat Strain Model. The work:rest ratios and water intake were revised to accommodate the differences between estimates.

d. The recommended rates of water intake and work:rest ratios were then validated, where possible, with existing data for soldiers wearing the BDU, Hot weather under varied climatic conditions.

e. Future plans include validating the sweating rates under simulated laboratory conditions and comparing the revised water doctrine to existing doctrine during U.S. Army Basic Training.

Encl 1.

Fluid Replacement Guidelines* for Warm Weather Training (Average Acclimated Soldier wearing BDU, Hot Weather).

Heat Category	WBGT Index, °F	Easy Work		Moderate Work		Hard Work	
		Work /Rest	Water Intake, Qt/h	Work /Rest	Water Intake, Qt/h	Work /Rest	Water Intake, Qt/h
1	78-81.9	NL	½	NL	¾	40/20 min	1
2	82-84.9	NL	¾	NL	1	30/30 min	1
3	85-87.9	NL	1	40/20 min	1	30/30 min	1¼
4	88-89.9	NL	1	30/30 min	1¼	20/40 min	1¼
5	> 90	NL	1¼	30/30 min	1¼	15/45 min	1¼

* Volumes listed are required to support work/rest times listed for each work level. NL, no limit to work time per hour. Hourly fluid intake should not exceed 1½ quarts. Daily fluid intake should not exceed 10 quarts.

NOTE: MOPP gear or body armor adds 10°F to WBGT Index. Rest means minimal physical activity (sitting or standing) and should be accomplished in shade if possible.

Easy Work	Moderate Work	Hard Work
• Weapon Maintenance • Walking Hard Surface at 2.5 mph, 30 lb Load • Manual of Arms • Marksmanship Training • Drill and Ceremony	• Walking Loose Sand at 2.5 mph, No Load • Walking Hard Surface at 3.5 mph, 40 lb Load • Calisthenics • Patrolling • Individual Movement Tech. i.e. low crawl, high crawl • Defensive Position Const. • Field Assaults	• Walking Hard Surface 3.5 mph, 40 lb Load • Walking Loose Sand 2.5 mph with Load

4. POC for this doctrine is CPT Scott Montain (DSN 256-4564/ Comm 505-233-4564).

Encl

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APPENDIX H

WORK:REST/WATER CONSUMPTION TABLE
(1998)

HEAT CAT	WBGT INDEX °F	EASY WORK		MODERATE WORK		HARD WORK	
		Work / Rest	Water Intake Qt/Hr	Work / Rest	Water Intake Qt/Hr	Work / Rest	Water Intake Qt/Hr
1	78–81.9	NL	1/2	NL	3/4	40/20 min	3/4
2	82–84.9	NL	1/2	50/10 min	3/4	30/30 min	1
3	85–87.9	NL	3/4	40/20 min	3/4	30/30 min	1
4	88–89.9	NL	3/4	30/30 min	3/4	20/40 min	1
5	> 90	50/10 min	1	20/40 min	1	10/50 min	1

- The work:rest times and fluid replacement volumes will sustain performance and hydration for at least 4 h of work in the specific heat category. Individual water needs will vary ± (plus/minus) 1/4 qt/hr.
- NL = no limit to work time per hour. Rest means minimal physical activity (sitting or standing) and should be accomplished in shade if possible.
- **CAUTION: Hourly fluid intake should not exceed 1 1/2 (one and one-half) quarts.**
- **Daily fluid intake should not exceed 12 quarts.**
- NOTE: MOPP gear adds 10°F to WBGT Index.

EXAMPLES		
EASY WORK	**MODERATE WORK**	**HARD WORK**
* Weapon Maintenance * Walking Hard Surface at 2.5 mph, ≥ 30 lb Load * Manual of Arms * Marksmanship Training * Drill and Ceremony	* Walking Loose Sand at 2.5 mph, No Load * Walking Hard Surface at 3.5 mph, < 40 lb Load * Calisthenics * Patrolling * Individual Movement Techniques, i.e., low crawl, high crawl * Defense Position Construction * Field Assaults	* Walking Loose Sand at 2.5 mph, with Load * Walking Hard Surface at 3.5 mph, ≥ 40 lb Load

Source: Memorandum, Office of the Surgeon General (DASG-HSZ), dated 29 Apr 98, subject: Policy

Guidance for Fluid Replacement During Training